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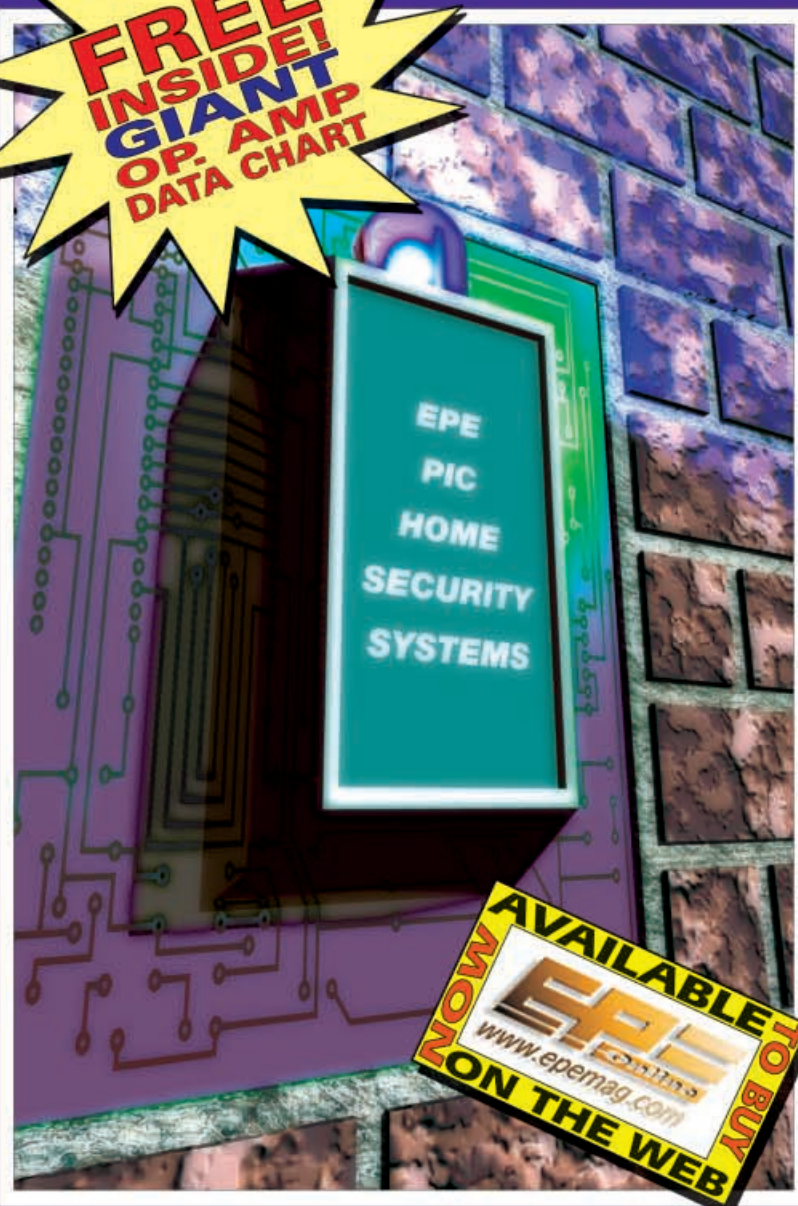
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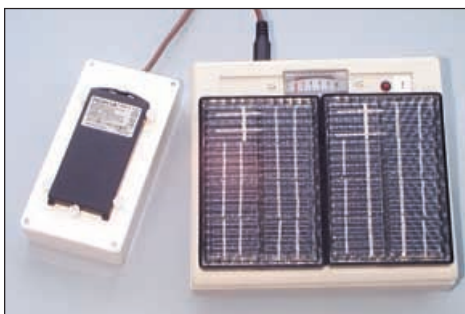
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NEXT MONTH

PIC BIG DIGIT DISPLAY



RECENTLY Display Electronics acquired several thousand individual electromechanical "big digits". These had previously graced the platforms of British Rail in 6-digit 7-segment clocks. The digits measure 12in. high, 9in. wide and 2.25in. deep (30.5cm x 23cm x 5.5cm). The angled display area is effectively 10in. high x 7in. wide (25.5cm x 18cm) and comprises seven bright-yellow hinged segments.

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The digits are ideal for use in any situation that requires a large electronically controlled display where the data is to be input intermittently. Applications that come to mind are sporting score boards, ticket draw results, display of outdoor temperature in public arenas – well, you've seen where large digits can be used, think up your own applications!

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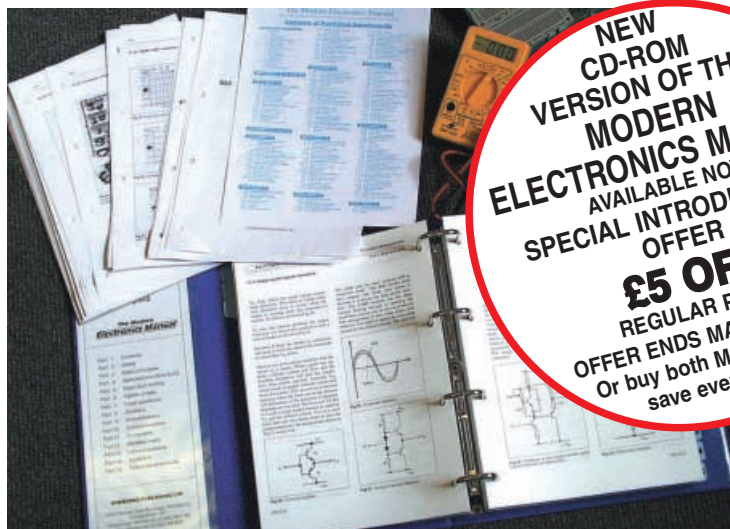


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WAY TO GO!

With so many developments in both electronics and computing plus the combination of these areas to allow such things as microcontroller programming etc., it's more and more difficult to try to keep *EPE* on track in our major areas of interest. Should we do more on programming languages and on programming microcontrollers from ranges other than the PIC devices from Microchip?

There is no doubt that other microcontrollers will feature in future projects – and indeed have featured in one or two past projects – but we do not feel it is sensible to start investigating too many software languages and their intricacies. We will stick to project building as our main area of interest and introduce the specialist PIC programming areas where we can – like this month's *Programming PIC Interrupts* article.

Having said that, let me assure those readers who do not want to go down the chip programming route that we will continue to cater for them. Not everything has to be programmed, fascinating and versatile though this technology is. So we have a varied content lined up for future issues, including a wide range of easy to build projects using both simple transistor and simple digital i.c. circuitry.

VARIETY

I think this issue is a good example of the variety of material we will continue to publish. Even if you are not into programming your own chips, John's *PIC Controlled Intruder Alarm* is an excellent and versatile project and, as with virtually all our PIC-based designs, is one that can be built without the need to understand the programming – just buy the pre-programmed chip for an easy to build project. Both the *Solar Charge And Go* and the *Electric Guitar Tuner* articles show the wide range of projects that can be built using very simple circuitry. So why not drag out that soldering iron and get stuck in.

Mike Kenward

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ELECTRIC GUITAR TUNER

ROBERT PENFOLD



Strike a chord with your group!

GUITAR tuner projects range from simple devices having l.e.d. displays to highly complex units using signal processing stages, frequency to voltage converters, and sophisticated displays. This unit is very much in the "cheap and cheerful" category, but it nevertheless works very well.

Guitar tuning is an application where the more sophisticated approaches tend to generate problems that take ever more electronics to solve. Most problems stem from the fact that the output waveform from a guitar tends to change quite dramatically during the course of a sustained note, with some of the harmonics becoming very strong at times.

True frequency measuring devices can have problems due to harmonics (multiples of the fundamental frequency) being measured at times, rather than the fundamental frequency itself. Without suitable signal processing

the tuning indicator can jump around, making precise adjustment very difficult.

IN COMPARISON

The guitar tuner featured here uses a very simple frequency comparison circuit that works just as well whether the input to the comparator is at the fundamental frequency or a harmonic. This avoids the need for any signal processing other than a simple input amplifier.

The display is just a single l.e.d. (light emitting diode) that flashes at a rate equal to the difference between the guitar's frequency and the correct frequency. Correct tuning is therefore indicated by a steady state from the l.e.d. indicator. The unit is powered from a small 9V battery and it is fully portable.

This project is simple enough to be tackled by a complete beginner at electronic project construction. No test equipment is

needed to set-up the finished unit, but an accurately tuned instrument or pitch-pipes are needed to provide reference frequencies.

HOW IT WORKS

The block diagram for the Electric Guitar Tuner project appears in Fig.1, and as will be apparent from this, the circuit is basically just an amplifier and an audio oscillator. An l.e.d. is connected between the outputs of these two stages. The amplifier has a high level of voltage gain so that its output signal will normally be a square-wave signal.

The audio oscillator also has an output waveform that is more or less square. A simple CR oscillator is used, and this has six switched resistors that provide output frequencies that are the same as the six open-string notes of a guitar.

The polarity of the indicator l.e.d. is such that it is switched on when the output of the amplifier is low and the oscillator's output is high. It is switched off with any other set of output states.

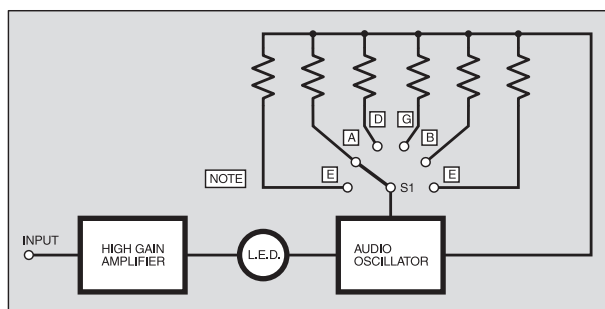


Fig.1. Block diagram for the Electric Guitar Tuner.

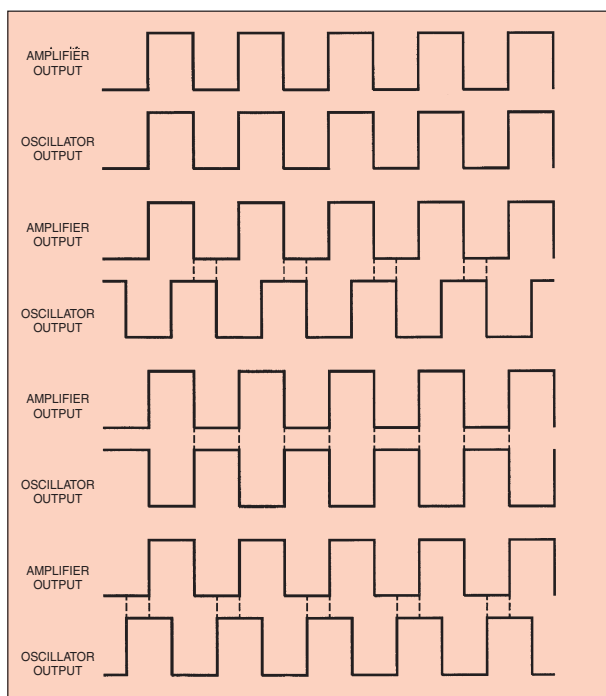


Fig.2. Output waveforms with various phase relationships between the two output signals. The dotted lines indicate when the l.e.d. is turned on.

In Fig.2, the top pair of waveforms represents the output signals from the amplifier and oscillator with the same output frequencies and the two signals in-phase. With the two signals always at the same state the l.e.d. is never switched on.

In the next pair of waveforms the two signals are still at the same frequency, but they are now 90 degrees out-of-phase. This results in the l.e.d. being switched on for 25 per cent of each cycle. The pulses from the l.e.d. are at too high a frequency for the individual pulses to be perceived, and the l.e.d. seems to be switched on continuously, but at less than full brightness.

In the third pair of waveforms the signals are 180 degrees out-of-phase, and the l.e.d. is now switched on for 50 per cent of each cycle. Again, the individual pulses cannot be seen, and the l.e.d. appears to be

standard non-inverting configuration. Some guitar pickups produce much higher output levels than others, and the closed loop voltage gain of IC1 has therefore been set very high so that strong clipping is produced at the output even when it is used with a low output pickup.

Negative feedback resistors R4 and R5 set the voltage gain at just over 60dB (1000 times). Resistors R1 and R2 bias the input of the amplifier and set the input impedance at just under 20 kilohms (20k). This produces a good match for most guitar pickups.

The oscillator uses IC2 in the standard 555 oscillator mode. A low-power version of the 555 timer i.c. is used in order to keep the battery drain quite low, and the total current consumption of the circuit is only about 8mA.

COMPONENTS

Resistors

R1, R2	39k (2 off)
R3	1k5
R4	2M2
R5, R7	2k2 (2 off)
R6	4k7
R8	100k

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Potentiometers

VR1, VR2	47k min enclosed carbon preset, horiz. (2 off)
VR3, VR4	22k min enclosed carbon preset, horiz. (2 off)
VR5, VR6	10k min enclosed carbon preset, horiz. (2 off)

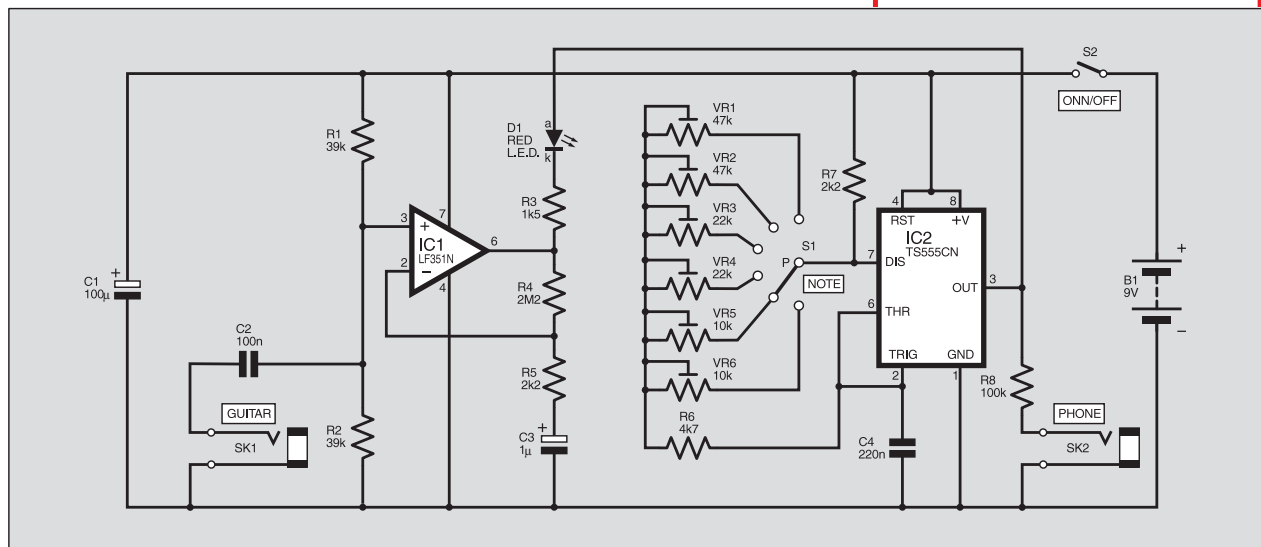


Fig.3. Complete circuit diagram for the Electric Guitar Tuner.

switched on continuously. It is at less than full brightness, but it is much brighter than with the signals 90 degrees out-of-phase. The drive current is set high enough to give reasonable brightness with the l.e.d. switched on for 50 per cent of the time.

In the final pair of waveforms the signals are 270 degrees out-of-phase, and the l.e.d. is again switched on for 25 per cent of the time. A further phase shift of 90 degrees would take things back to the beginning with the signals in-phase and the l.e.d. switched off.

With the guitar slightly off-tune so that there is a small mismatch in the two frequencies, the output signals gradually slip in and out of phase. As they do so, the l.e.d. varies from maximum brightness with the two signals 180 degrees out-of-phase, to fully switched off with the signals in-phase.

This produces the flashing from the l.e.d. at a rate equal to the difference in the two frequencies, or the "beat rate" as it is known. A lack of activity from the l.e.d., whether it is fully switched on, turned off, or anywhere in between, indicates that the two frequencies are accurately matched.

CIRCUIT OPERATION

The full circuit diagram for the Electric Guitar Tuner is shown in Fig.3. The amplifier uses operational amplifier IC1 in the

Resistor R7 provides one of the timing resistances, and the other one is made up from series resistor R6 and whichever of the six preset potentiometers (VR1 to VR6) is switched into circuit using rotary switch S1. The six presets provide the six reference frequencies, with VR6 and VR1 being used for the top and bottom E notes respectively. The value of R7 is kept low in comparison to the other timing resistances in order to give an output waveform at pin 3 of IC2 that has a mark-space-ratio of approximately 1-to-1.

Indicator D1 is the l.e.d. and R3 is the current limiter resistor. The l.e.d. current is about 4mA, but as the l.e.d. is never switched on for more than about 50 per cent of the time the average current never exceeds about 2mA. It is, therefore, advisable to use a high-brightness l.e.d. that is designed for operation on low currents.

Socket SK2 can be used to monitor the output of IC1 using a crystal earphone, and resistor R8 attenuates the output signal to a suitable level. The circuit can drive medium impedance headphones, as used with personal stereo units, if R8 is reduced to a value of 10 kilohms. For best results the phones should be driven in series.

The actual voltage from a 9V battery varies significantly during its operating life, but there is no need to power the

Capacitors

C1	100uF radial elect. 10V
C2	100nF polyester, 5mm lead spacing
C3	1uF radial elect. 50V
C4	220nF polyester or polycarbonate, 5mm lead spacing

Semiconductors

D1	5mm or 3mm low-current (2mA) red l.e.d., with panel mounting clip
IC1	LF351N bi-f.e.t. op.amp
IC2	TS555CN low-power timer i.c.

Miscellaneous

S1	6-way 2-pole rotary switch (only one pole used)
S2	s.p.s.t. min. toggle switch
SK1	standard 6-35mm mono jack socket
SK2	3-5mm mono jack socket
B1	9V battery (PP3 size), with connector clips

Small instrument case, size to suit; 0.1-inch stripboard, having 32 holes by 28 strips; 8-pin d.i.l. socket (2 off); control knob; multistrand wire; solder pins; solder; etc.

Approx. Cost
Guidance Only
excluding batt. & case

£11

circuit by way of a voltage regulator. One advantage of a 555 oscillator is that its method of operation ensures that there is no significant change in output frequency even with quite large variations in the supply potential.

CONSTRUCTION

The Electric Guitar Tuner circuit is built on a piece of stripboard and the top-side component layout, interwiring and details of breaks required in the underside copper tracks are shown in Fig.4. A board having 32 holes by 28 copper strips is required, and this is not one of the

standard sizes. A larger piece of stripboard must therefore be trimmed to size using a small hacksaw.

The breaks in the copper strips can be made with a handheld twist drill bit of about 5mm in dia. Make sure that the strips are cut properly, with no fine tracks of copper left behind. The two mounting holes are 3mm in diameter and they will accept M2.5 mounting bolts.

The board is now ready for the components and link-wires to be added. Neither of the two integrated circuits are sensitive to static charges, but it is still a good idea to fit them on the board via i.c. holders.

Ideally the six preset potentiometers would be multi-turn "trimpots", which have better resolution and are easier to adjust accurately than "bog standard" pre-sets. It should not be difficult to modify the layout to accept vertical trimpots, but six of these components will substantially boost the cost of the project. Ordinary miniature preset potentiometers will suffice, and are used on the prototype, but they must be adjusted very carefully.

In order to fit into the layout easily capacitors C2 and C4 should be types that have 5mm (0.2-inch) lead spacing. It is preferable to use a high quality component

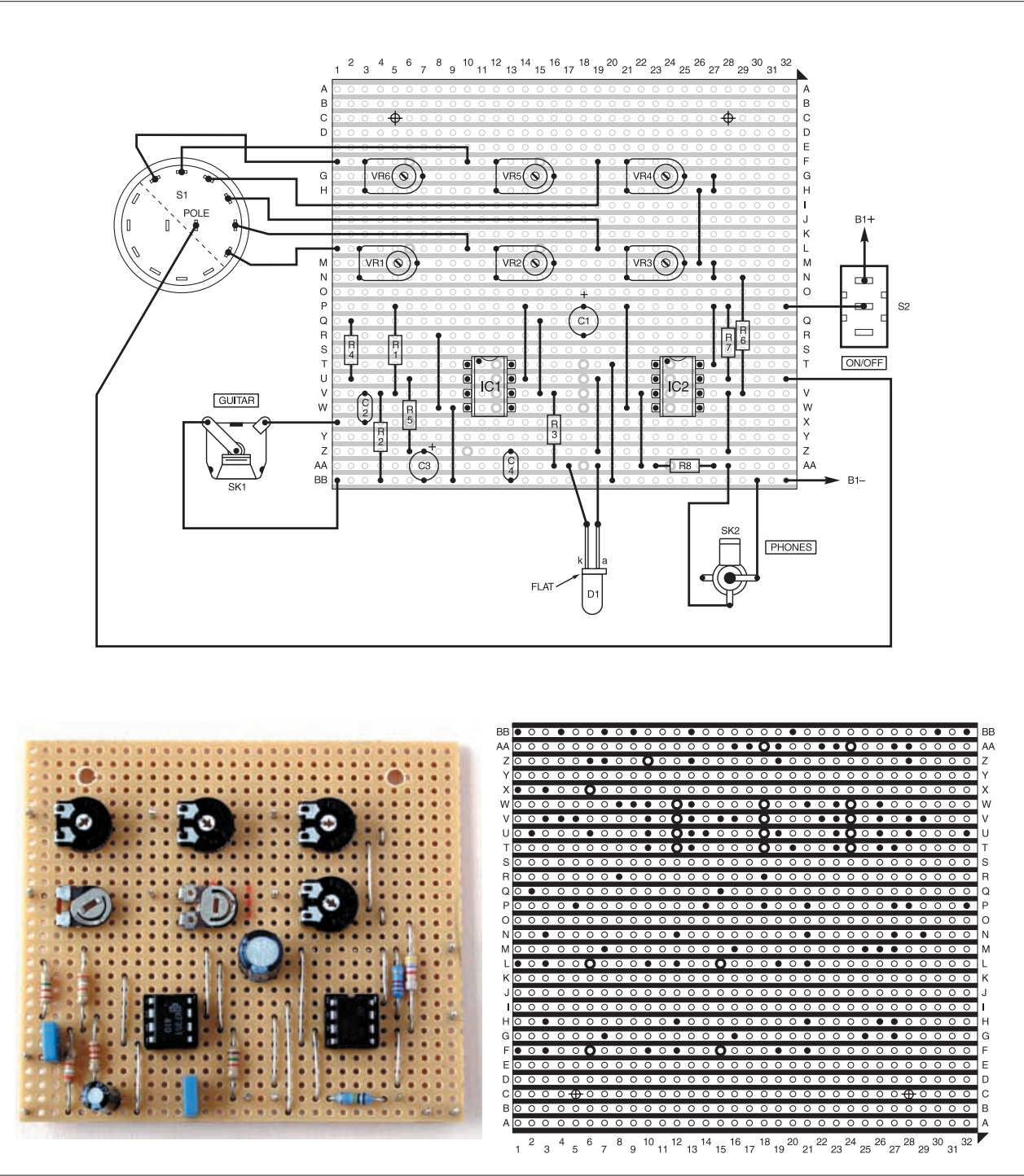


Fig.4. Electric Guitar Tuner stripboard topside component layout, interwiring to off-board components and details of breaks required in the underside copper tracks. The complete circuit board is shown above left.

for C4 so that any frequency drift with changes in temperature is minimised. A polycarbonate capacitor is probably the best choice, but a good quality polyester component should give good results. Most ceramic types have inadequate short and long term stability and should *not* be used.

Practically any small or medium size instrument case is suitable for this project. Alternatively, a diecast aluminium box is a good choice if maximum toughness is required. The exact layout of the unit is not important, but try to arrange things so that the wiring from socket SK1 to the circuit board is no more than a few centimetres long.

Due to the high gain of IC1, plus the fact that its input and output are in-phase, stray feedback to long input wiring could cause severe instability. A **screened cable must** be used to connect SK1 to the circuit board if this cable is more than a few centimetres long.

TUNE SWITCH

Switch S1 is a 6-way 2-pole rotary switch, but in this circuit only one pole is used. Consequently there are no connections to seven tags of this switch. Modern switches of this type invariably have an adjustable end-stop, and in this application the end-stop should obviously be set for 6-way operation.

The circuit board is bolted in place on the base panel of the case. If a metal case is used it is **essential** to use spacers of at least 6mm in length over the mounting bolts, between the case and the board. This will keep the connections on the underside of the board well clear of the metal case.

Even if a plastic case is used it is still necessary to use spacers, washers, or a couple of extra nuts to provide at least a small stand-off between the case and the board. Most makes of stripboard are quite brittle, and there is otherwise a risk of the board buckling and cracking as it is bolted in place.

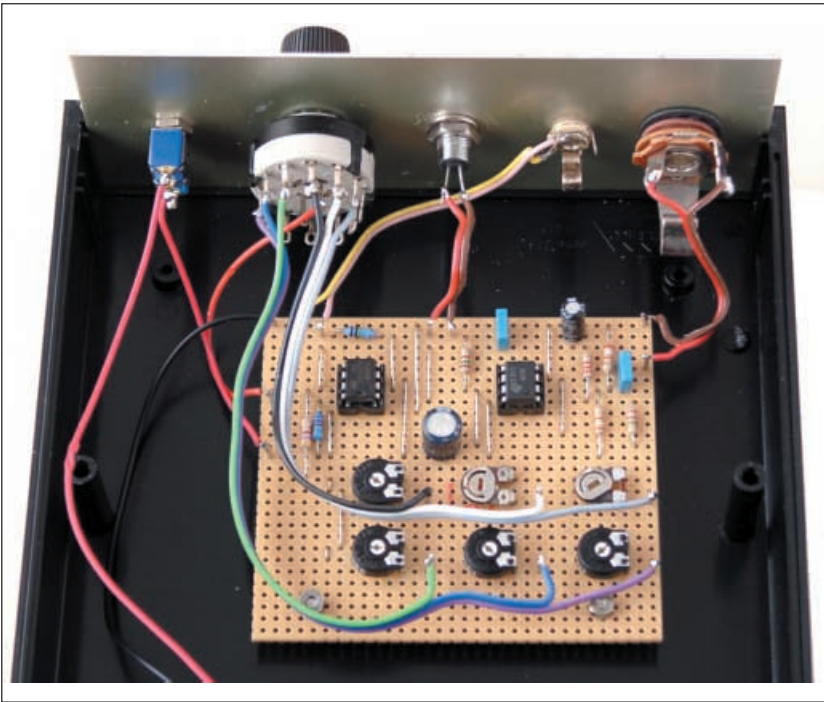
Details of the hard wiring are also included in Fig.4, and this is largely straightforward. The polarity of l.e.d. D1 is unimportant in this case. If it is connected the wrong way round the on and off states will be swapped, but this is of no consequence and the unit will still work perfectly.

ADJUSTMENT AND USE

If a suitable frequency meter is available it can be used to set the correct output frequencies from IC2. In order to obtain adequate accuracy an instrument having a gate time of 10 seconds and a resolution of 0.1Hz is required. The correct output frequencies to the nearest 0.1Hz are shown in Table 1.

Table 1: Output Tuning Frequencies

Note	Frequency	Preset
E	82.4	VR1
A	110	VR2
D	146.8	VR3
G	196	VR4
B	246.9	VR5
E	329.6	VR6



Interwiring from the circuit board to the front panel mounted components.

Another method is to monitor the output of IC2 using an earphone connected to socket SK2 and then tune the presets “by ear”. Either pitch pipes or an accurately tuned instrument is needed to provide reference notes that the unit can be tuned against.

A third method is to connect an accurately tuned guitar to socket SK1 and then use this as the tuning reference. An electronic keyboard instrument can be used in the same way, but make sure it is set for a normal musical scale with middle A at 440Hz. A normal screened jack lead is used to connect the electric guitar or other instrument to SK1.

With preset potentiometer VR1 selected using rotary switch S1, play the lower E note and adjust VR1 for the lowest flash rate from the l.e.d. indicator D1. If the output frequency of IC2 is well away from the correct figure the flash rate will be so high

that the l.e.d. will seem to light up continuously. Adjust VR1 to produce a perceptible flash rate first, and then carefully adjust it for the lowest possible rate.

The same basic procedure is then used to give the other five preset potentiometers suitable settings. There should be no difficulty in matching the frequency of IC2 to within 0.1Hz of each reference note.

In use the Electric Guitar Tuner is used in much the same way, but each note of the guitar is adjusted for the lowest possible flash rate. The initial tuning error might be quite large when a new string is fitted, and the guitar must then be adjusted to produce perceptible flashing from the l.e.d. indicator first. It can then be adjusted for the lowest flash rate.

The simple flashing light indicator does not show the direction of any tuning error, but with a little practice it is still quite easy to home in on the correct setting. □



New Technology Update

FinFET devices feature ultra thin silicon fins that enable short channels to be used in CMOS production, yet again reducing chip sizes. Ian Poole reports on their pending introduction.

THERE are many stories around about how semiconductor technology as we know it today is reaching the end of the road. It is only possible to miniaturise the technology to a given point beyond which no further improvements are possible. For the most part it has been possible to overcome the limitations that were thought to exist, but now it does seem that the development of the standard form of CMOS is reaching its final limits.

It has been found that since gate lengths went into sub micron sizes, the drain of the CMOS MOSFET has given rise to problems. When gate lengths fall to below about 0.5 microns the electric field around the drain can easily rise to the levels where the source-drain leakage increases considerably. In extreme cases it can give rise to a punch-through effect whereby the device permanently fails.

CMOS Structure

CMOS devices have been the mainstay of i.c. technology for very many years. Only a few years after the introduction of i.c.s it was feared that the limits of integration would soon be reached because the heat dissipated in the conventional circuits used could not be removed in such a way that chip operating temperatures could be kept within satisfactory limits.

Whilst work was undertaken to improve the ways in which heat was removed, the real breakthrough occurred with the development of CMOS technology that dramatically reduced the current drawn by the circuits in the i.c., and accordingly the level of heat produced was also reduced.

Complementary metal-oxide semiconductor, or CMOS, is formed by the combination of PMOS and NMOS (*p*-type and *n*-type channel semiconductors), see Fig.1. The two enhancement mode devices are fabricated on a silicon chip and connected in a push-pull configuration.

Whilst the level of heat produced by CMOS circuits is dramatically less than

that generated by other technologies, this does come at the cost of an increase in the level of fabrication complexity.

However, this is more than compensated for by the increase in the level of integration that can be achieved. Also, early devices were not as fast as other technologies, but since then their performance has been very considerably improved.

The CMOS process has been particularly successful, being used for very many years. Feature sizes have steadily been reduced to enable it to meet the requirements for today's technology, but now it appears that the limit is in sight for the standard technology in terms of providing for the very latest chips with their minute feature sizes.

Resolving the Problems

There are a number of ways that have successfully been used to overcome the problems that occur with CMOS. One is to make the channel depletion region more effective by increasing the level of doping. However, this also has the effect of increasing the *on* resistance for the device. In turn this degrades the overall performance, and in particular the frequency response.

Another alternative that is being used by some manufacturers is to use an insulating substrate in a process known as silicon-on-insulator (SOI). Using this approach the substrate is depleted of all electrons and in this way the electrons are forced to move through the very thin channel. This ensures that all the current is forced through the relevant areas of the chip.

Further developments of this technology have made the channel very thin. In this way, what is known as the floating body effect is eliminated. This effect is an unwanted feature of SOI devices. One team has reported a 50nm thick channel whilst another has reported reducing the channel thickness to just 7nm. However, for this very thin channel, a gate oxide layer that was four times as thick as most gate oxide layers today was used.

FinFET

Another method that can be used to overcome the problem is to use a double gate. This normally entails placing a gate on top and below the channel. In this way the bulk silicon is not able to be a problem. Achieving this is not easy, though. The techniques required in the i.c. fabrication process dramatically increase the overall cost.

A novel approach has been adopted to overcome the problem. By rotating the

structure through ninety degrees, gates can be placed on either side of the channel.

Despite its rather novel approach, the FinFET, as it is known, is very close to the traditional double gate FET structure seen in the textbooks. It features the ultra thin silicon fin that enables the short channel effects to be overcome, raised polysilicon drain and source to reduce parasitic effects, two gates that are self aligned to each other and to the source and drain regions. The other advantage is that the FinFET has been produced in both *n* and *p* channel varieties allowing FinFET CMOS i.c.s to be manufactured.

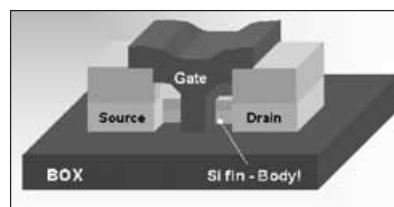


Fig. 2. FinFET structure.
Courtesy www.ecedha.org.

The gate of the latest FinFETs are around 18 nanometers long and this corresponds to the dimensions of just 100 atoms. This is about ten times shorter than the standard dimensions used in transistors. For the future it is hoped to cut the FinFET dimensions by about half, although further work will be required to achieve this.

Advantages

The miniaturisation that the FinFET will provide can be utilised by chip designers to pack even more into future designs. As the new transistor is ten times smaller than existing ones it will allow 100 times as many devices to be packed into the same space, and will allow chip makers to significantly improve the functionality of microprocessors, or to shrink chip designs to improve yields and reduce prices.

It is expected that existing CPUs may be remodelled using the new transistor design, so it is possible that the new transistor will appear in new versions of existing processors. In this way the new technology can be introduced into production as soon as possible without the need to wait for the development of the next generation of processors with completely new designs. As such it should be possible to see the new technology hitting the markets before too long.

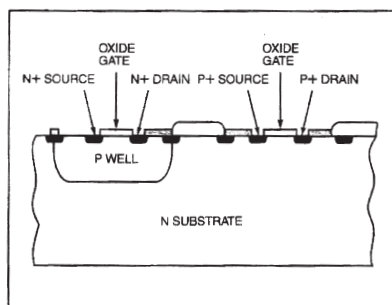


Fig.1. CMOS structure.

VIDEOS ON ELECTRONICS

A range of videos selected by *EPE* and designed to provide instruction on electronics theory. Each video gives a sound introduction and grounding in a specialised area of the subject. The tapes make learning both easier and more enjoyable than pure textbook or magazine study. They have proved particularly useful in schools, colleges, training departments and electronics clubs as well as to general hobbyists and those following distance learning courses etc



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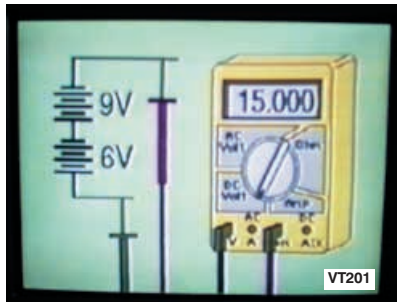
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VT303 54 minutes. Digital Three; **Registers and Displays** is your next step in obtaining a solid understanding of the basic circuits found in today's digital designs. Gets into multiplexers, registers, display devices, etc.

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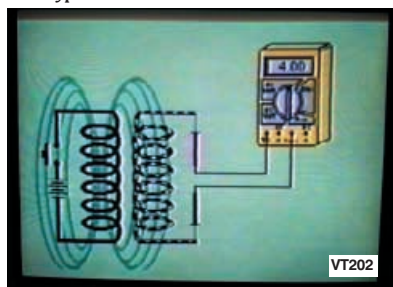
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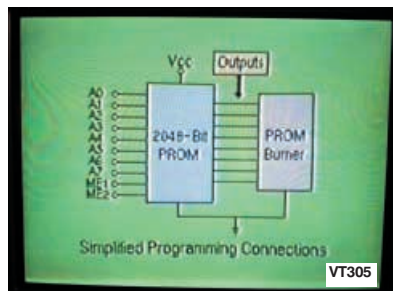
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FAST-TRACK IDENTITY RECOGNITION

Body language detectors can replace fingerprints for identification. Barry Fox reports.

FINGERPRINTS, face pattern recognition, iris scans and signatures are already old hat, says Spinnaker International of Plymouth in a patent for a completely different type of security check (GB 2 359 890).

A cash-in-transit box contains an accelerometer, which continually senses motion up and down and side to side. Memory in the box stores information on the motion pattern created when an authorised security guard is carrying the box. If someone else grabs the box, or if the guard behaves unnaturally, running when chased or being driven off in a vehicle, the signals from the accelerometer no longer match the stored gait pattern. The box then detonates a dye pack to spoil the contents.

The system can also be used to protect portable computers, which disable if carried by someone unfamiliar, or provide early warning of suspect vibration in a car suspension or engine.

The Massachusetts General Hospital in Charlestown also has no confidence in conventional biometrics, and is patenting a way of using the human anatomy as a password (WO 01/73680). The object is to identify individuals without close inspection. A pair of video cameras simultaneously record a series of images of the subject, walking naturally.

Arm, leg and torso length are then mapped into reference graphics, together with characteristic body shape and motion, such as a head roll, arm swing, leg stride and shoulder posture. The reference images are stored and compared with images from cameras mounted by a secure area. If the image characteristics match access is authorised.

HOW TO BE KEENE

Keene Electronics 2002 catalogue seemingly contains everything that you could possibly want in the way of audio-visual equipment and accessories. The company tell us that they sell "interesting, useful and sometimes hard to find bits and pieces designed to make your life easier, whether you're a camcorder enthusiast, home cinema fan or general gadget addict".

Their catalogue is nicely produced, in full-colour A4, with around 100 pages. It can be obtained free of charge by anyone that asks for it, says Alan Quinby of Keene.

Contact Keene Electronics, Dept. EPE, Unit 9, Old Hall Mills, Business Road, Little Eaton, Derbyshire DE21 5DN. Tel: 0870 990 9000. Fax: 01332 830551.

Email: sales@keene.co.uk

Web: www.keene.co.uk

SCIENCE EXHIBITION

ONCE a year, the Royal Society – the UK's independent academy of science – makes sure that you have the chance to meet some of the scientists and engineers working on the UK's most innovative research.

This year you can come face-to-face with cutting-edge science and engineering at the Society's *Summer Science Exhibition* from 2 to 4 July, and entry is free. Among the 20 exhibits will be malaria vaccines, cryptography and mapping of the oceans in respect of ocean forecasting and climate change monitoring.

For more information phone the Royal Society on 020 7451 2574, or browse www.royalsoc.ac.uk.

Neon String

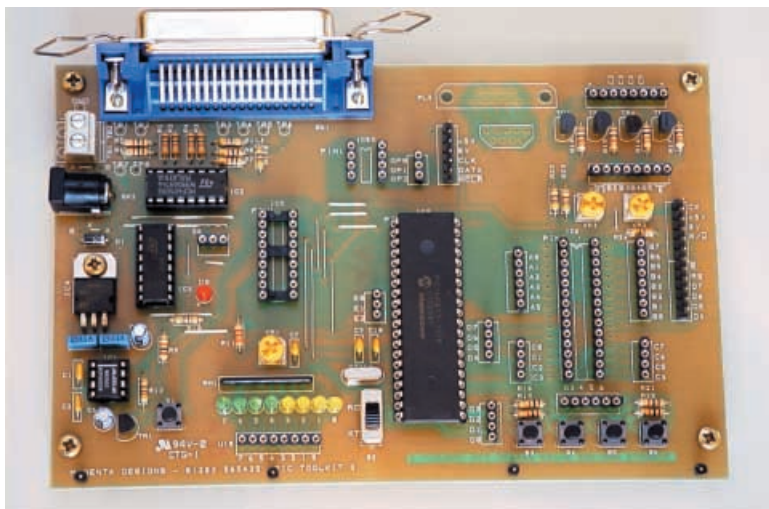
A SMALL British business, Inntact Electronics, seems to be attracting international attention, including NASA. Inntact specialise in electroluminescent (EL) panels and EL string (sometimes called neon string), and the inverters that power them. EL products produce a very even light and generate no heat, resulting in improved illumination and significant power saving.

NASA are replacing the I.e.d. systems of their escape guidance systems with these EL devices. BAE have also approached Inntact with regard to powering the EL displays in the Euro Fighter simulators.

The neon string is so flexible you can tie it in knots, and it is just 2.5mm in diameter, producing a bright crisp light without heat. It can produce green or blue light and be operated at 12V for automotive use. A trial kit is available, consisting of one metre of string with connectors and power pack for £29.99 including delivery and VAT.

For more information contact Inntact Electronics, Dept. EPE, Unit 5, Butterley Croft, Whiteley Road, Ripley, Derbys DE5 3QL. Tel: 01773 570008. Email: inntact@aol.com. Web: www.inverter-solutions.co.uk. (Also see the advert in this issue.)

MAGENTA TK3 KIT-UP



Mail order specialists Magenta Electronics have launched their own printed circuit board and kit for *EPE Toolkit Mk3/TK3*.

Based on the author's original p.c.b. as published in Oct '01, the Magenta board has been somewhat redesigned to include a d.c. power socket with a reverse polarity protection diode. Facilities for adding a 9-way p.c.b. mounted serial connector have been added as well.

The board is printed with component identification legends and a solder mask assists reliable soldering during assembly. Turned-pin connectors are used at strategic points to allow easy link-wire connection between the p.c.b. and an external breadboard.

The kit includes components, p.c.b., breadboard, I.c.d. and a choice of PIC microcontroller. The prices are £34.99 for the PIC16F84 version, and £39.99 for the 'F877. UK post and packing is £3.

For more information contact Magenta Electronics, Dept. EPE, 135 Hunter Street, Burton-on-Trent, Staffs DE14 2ST. Tel: 01283 565435. Fax: 01283 546932.

PIC AND MIX



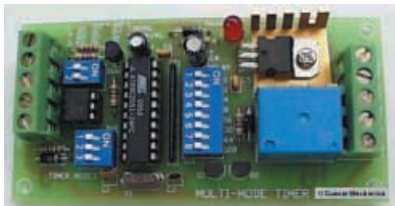
MICROCHIP'S new PICDEM MSC1 demonstration board has been designed to simplify the design of mixed signal applications that use the PIC16C781/2 configurable analogue microcontrollers.

The board allows users to configure the PIC's multiple digital and analogue peripherals and download the configuration for quick evaluation. The system includes an evaluation package with an easy to use graphical user interface and code generator.

Designers can configure the inputs and outputs of each peripheral module, load and view the contents of the Special Purpose Registers, operate a dynamic conversion loop for scoping the DAC module output, or continuously monitor the ADC input channels.

For more information browse www.microchip.com.

QUASAR TIMES SEVEN



QUASAR Electronics comment that "no-one can call themselves an electronics hobbyist unless they have built a timer". From this assertion we assume that your hobbyist attributes will increase 7-fold when you build Quasar's new Multi-Mode Timer kit, which features seven timers!

The seven different timing modes of Quasar Kit 3141 are microcontrolled. Four crystal controlled timing periods are provided, covering the ranges 1 to 255 and 10 to 2550 in seconds or minutes.

Trigger options range from simple push-button to electrically isolated voltage sources. The trigger inputs are optoisolated. Output is to a high quality mains rated relay. Timing modes and delay ranges are set using on-board DIP switches and there are screw terminals for all connections.

Available by mail order, KIT 3141 is just £14.95 (or £23.95 ready-assembled), including VAT. UK postage is £2.

For more information contact Quasar Electronics Ltd., Dept. EPE, PO Box 6935, Bishops Cleeve, CM23 4WP. Tel: 01279 467799. Fax: 07092 203496.

Email: epesales@quasarelectronics.com.
Web: www.quasarelectronics.com.

MATHS AND BROOKLANDS

ARE you anxious about algebra? Do symbols and equations confuse you? Can you make sense of Boolean logic? Brooklands College in Surrey has asked these probing questions, and believe they have the solution if you answer yes to them.

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On-line tutor support is available throughout the course and assessment is based on seven tutor-marked assessments. Successful students will be awarded a Brooklands College Certificate that will record the total assessment mark and the grade awarded (Pass, Merit or Distinction).

The first part of the course can be sampled before you enrol and further on-line electronics courses are currently being developed. The full course costs only £29.99.

To find out more, browse <http://online.brooklands.ac.uk>

Spicing Up Electronics

RD Research have introduced B² Spice AD Version 4, replacing the widely used B² Spice 2000. Version 4 uses what they describe as the "Berkeley 3F5" simulation engine to accurately simulate the way electronic circuits work. Users can design analogue and digital circuits quickly and easily. This new version also includes the design of r.f. circuits.

The software is priced at £229 and comes complete with a model library of over 8000 parts. Complex circuits can easily and rapidly be designed on screen and subjected to a range of tests. The results are displayed in graphs, tables or on "virtual meters".

For more information contact RD Research, Dept. EPE, Research House, Norwich Road, Eastgate, Norwich NR10 4HA. Tel: 01603 872331. Fax: 01603 879010.

Email: rd.research@paston.co.uk. Web: www.looking.co.uk.

New Ham Licence

THE DTI Radiocommunications Agency has introduced a new ham radio licence, called the Foundation Licence. It is aimed at young people to help get them interested in radio, electronics communications and computers, with a view to them possibly pursuing a career in the subjects. The youngest person so far taking the Foundation Licence course is an 8-year old girl.

To view the Foundation Licence syllabus and for more information on the new licence visit www.qsl.net.

RADIO SHACK

RADIO Shack has been a household name for many years, especially to those living in the USA or who used to frequent the Tandy stores in the UK. Radio Shack was founded in 1921 and has become one of the world's largest retailers of consumer electronics products with over 5000 company-owned stores in the USA and in excess of 2000 in over 38 other countries.

RUSK Ltd has become the licensed distributor for Radio Shack in the UK. It was established as a UK company in the year 2000 to service the requirements of an existing network of ex-Tandy dealers and to develop new exciting business opportunities within the retail electronics market.

The company is said to be a "one-stop-shop" for electronics products, supplying retailers nationwide with over 3000 exclusive RadioShack branded products. It is also actively seeking the involvement of other retailers.

We have recently received Radio Shack's latest catalogue. At over 440 pages, the catalogue well illustrates why it is that the company's products are well respected. In addition to a very wide range of consumer electronic products, from amplifiers to weather stations, the catalogue contains a range of accessories such that any home electronics constructor is likely to need, from capacitors and resistors to transistors and i.c.s. etc.

The catalogue costs £1.99 (plus P&P) which is refundable with your next order valued at £10 or over.

For information on your nearest RadioShack stockist, or to order a catalogue, call 01543 468855. Email: info@rs-rusk.com. Web: www.radioshack.com.

WORKBENCH DEAL FOR STUDENTS

ADEPT Scientific tell us that Multisim and Ultiboard, the award-winning electronics software from Electronics Workbench, is now available to students in a suite for only £65, excluding VAT and delivery.

Multisim 2001 is the latest version of the renowned circuit simulation software used extensively in both industry and teaching. Adept say that it is the ideal tool for students to develop their skills in electronic circuit design. With this software, students can create circuits, analyse pre-built circuits, work through virtual laboratory assignments and simulate circuit behaviour.

Ultiboard 2001 is the latest version of the highly successful p.c.b. layout software, also from Electronics Workbench. It provides a comprehensive design flow, from board set-up and component trace placement, to file/report generation for manufacturing and assembly. It includes a large library and built-in autorouting. It has powerful visualisation tools which enable students to easily view and navigate board designs.

For more information contact Adept Scientific plc, Dept. EPE, Amor Way, Letchworth, Herts SG6 1ZA. Tel: 01462 480055. Fax: 01462 480213.

Email: ewb@adeptscientific.co.uk.
Web: www.adeptscience.co.uk.

INGENUITY UNLIMITED



Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere**. The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.)

Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE WORTH £586

- 100MS/s Dual Channel Storage Oscilloscope
- 50MHz Spectrum Analyser
- Multimeter • Frequency Meter
- Signal Generator

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours. Every 12 months, Pico Technology will be awarding an ADC200-100 digital storage oscilloscope for the best *IU* submission. In addition, a DrDAQ Data Logger/Scope worth £69 will be presented to the runner up.

Switch Mode Regulators – Saves Batteries

OFTEN when making portable devices there is a need for a regulated 5V supply, typically to power either logic or a microcontroller. Usually a linear regulator, such as a 7805, is used to derive this supply. Such regulators are quite wasteful because the current into such a regulator is always greater than the current out of it and there is a voltage drop across the regulator as well.

When running 5V logic from a 9V supply the regulator is wasting almost as much power as the whole device is using. If running the system from a 12V battery, such as a key fob battery, then more power is wasted than is used. For example, with an input of 9V, an output 5V @ 500mA, using $P=IV$ the input power = 4.5Watts, output power = 2.5W. Wasted power = 2W, efficiency = $2.5 / 4.5 = 55\%$.

If the input is 12V then the input power = 6W, the wasted power is 3.5W and the efficiency falls to 42%. The wasted power is dissipated as heat, and so the regulator must be mounted on a heatsink.

Switch mode power supplies (SMPSUs) convert one voltage to another voltage much more efficiently. Under the right conditions they can draw less current (at a higher voltage) than they supply to the load (at lower voltage).

In the past, switch mode supplies have been extremely tricky devices to use, requiring specialist knowledge, but now several manufacturers produce switch mode chips which have everything needed to make switch mode converters. The datasheets for these devices give very good application data to assist designers and some manufacturers even give out software to design the whole circuit according to user input parameters.

As an example, the circuit diagram of Fig.1 is based on National Semiconductor's LM3578 switch mode converter. The entire circuit costs about half as much as a 9V PP3 alkaline battery. The circuit's efficiency is summarised below:

Output 5V@180mA	Input 9V@141mA
efficiency: 71%	
Output 5V@360mA	Input 9V@290mA
efficiency: 69%	
Output 5V@540mA	Input 9V@450mA
efficiency: 67%	
Output 5V@720mA	Input 9V@620mA
efficiency: 65%	
Output 5V@180mA	Input 12V@108mA
efficiency: 69%	
Output 5V@360mA	Input 12V@220mA
efficiency: 68%	
Output 5V@540mA	Input 12V@380mA
efficiency: 59%	
Output 5V@720mA	Input 12V@600mA
efficiency: 50%	

In addition the circuit can output 500mA for long periods without any need for a heatsink. The minimum input voltage that the circuit needs to produce regulated 5V output is about 7.3V. The circuit is generally not recommended for sensitive analogue circuitry

as it does have a small amount of ripple on the output.

The circuit is straightforward to build. The inductor current rating should be about the same as the load current for best operation, and inductors can be connected in series or in parallel to achieve the desired value. The diode D1 should be a Schottky type as the circuit runs at high frequency. It is possible to add current limiting by inserting a resistor into the circuit between pin 8 and pins 7 and 6.

Imaginative

The circuit's operation may be understood intuitively. Imagine a square wave with a 50% duty cycle: the average voltage out of such a circuit is half the peak voltage of the square wave. All that is needed to convert such a square wave to d.c. is a circuit that takes the average of its input; a low-pass filter is such a circuit.

Many low-pass filters use resistors and capacitors, but resistors are not desirable in power circuitry and therefore in the SMPSU the low-pass filter uses an inductor and a

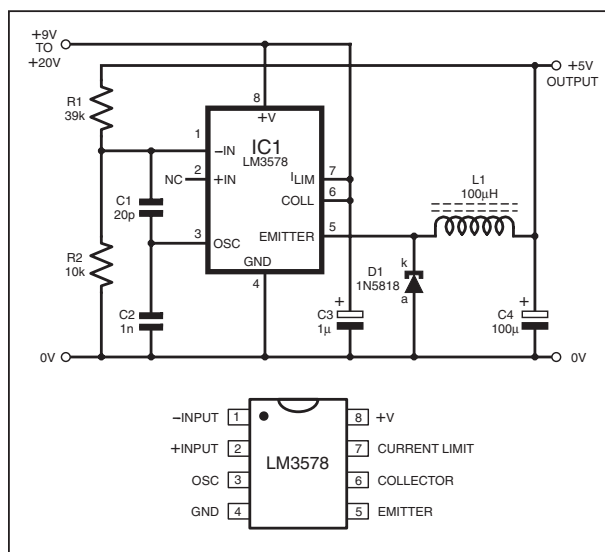


Fig.1. Circuit diagram for a Switch Mode Regulator.

capacitor. The Schottky diode provides a path for the inductor current when the "switch", which produces the square wave, is off.

Regulation is achieved by feeding back the output voltage via a resistor divider back into the device. Inside the i.c. the voltage on pin 1 is compared with a 1V reference. If the voltage on pin 1 is too high then the output voltage must be too high and so the i.c. reduces the duty cycle of the square wave, which drops the output voltage – a classical application of negative feedback.

We can now see why the circuit is efficient. If the input voltage is double that of the output voltage then the square wave's duty cycle will be about 0.5 (50%). This means that the circuit is only drawing current half the time. In addition the only major losses in the circuit are in the switch which produces the square wave, and in the diode.

These losses are small owing to the low voltage drops across the devices when in their on state. So next time an efficient power supply is needed, consider using these simple switch mode devices in your application.

Samuel Ginsberg,

TEACH-IN 2002

Part Six – Magnetic Sensors, Interference and Noise

IAN BELL AND DAVE CHESMORE



Making Sense of the Real World: Electronics to Measure the Environment

OVER the last couple of months we have looked at differential signals and circuits which help us reduce the effects of electrical interference, drift, and temperature dependence in sensor circuits. To fully protect our circuits from interference, though, we must also consider practical matters related to wiring and construction, such as shielding and grounding.

Electrical interference is not the only noise effect you may need to consider when designing sensor systems. So we will also look at some "other" sources of interference and at the random noise that is generated within the circuits and sensors themselves.

On the sensor side of things this month we study magnetic sensors, problems with switch bouncing in mechanical sensors and building a simple wind speed meter using a magnetic sensor.

NOISE ANNOYS

The unwanted signals present in electronic systems are known as **noise**. Noise is important in sensor systems because it limits measurement of low-level signals and degrades accuracy of measurement. Noise also limits maximum gain for amplifiers, as sufficiently high gain will result in the amplifier saturating simply due to the noise from the source or the input stage.

Noise may be present as part of an input signal (e.g. it may come from a sensor along with the wanted sensor signal), or it may be introduced by the circuitry (e.g. amplifier) used to process the signal. Noise may also come from outside or elsewhere in the system, coupled or picked up inadvertently and added to the signal being processed – this is often called **interference**.

Noise generated within components is generally random in nature and has a wide frequency range, whereas interference may produce unwanted signals at very specific frequencies.

Examples of interference that you may be familiar with include poorly suppressed ignition in cars which interferes with the car radio and mains hum picked up in hi-fi equipment. In some fields, notably the military, interference may be deliberate to **jam** radio signals.

ELECTRICAL INTERFERENCE

Sensor systems and other electronic circuits can be adversely affected by signals from other parts of the system or from outside, being inadvertently picked up and added in with the wanted signal. External signals may get into your circuit through **electrostatic**, **electromagnetic** and **magnetic** coupling:

- In electrostatic coupling a high impedance part of your circuit acts like one plate of a capacitor
- In magnetic coupling a loop in your circuit acts like the secondary of a transformer
- In electromagnetic coupling parts of your circuit act like antennae

Mains hum signals (at 50Hz/60Hz) and radio frequency interference from other electronic systems such as phones and computers are obvious examples of external noise a circuit or sensor is subject to will vary greatly depending on its location. The problem will obviously be worse close to

power lines, electrical machines and equipment such as TV sets.

Signals in one part of your circuit can find their way into other parts of the circuit where they cause problems. A common example of this is the clock of a digital section of the circuit getting into an analogue section, via the power supply lines or by capacitive coupling to high impedance points. Careful circuit design and construction can greatly reduce these problems.

SHIELDING AND GROUNDING

In the following discussion the boxes labelled Circuit 1 and Circuit 2 in the accompanying schematics may be any subsections of the circuit of interest. Typically in the case of this series, Circuit 1 will be a sensor, possibly with associated circuitry (power supply, potential divider, bridge circuit etc), and Circuit 2 may be an amplifier. However, the implications of our discussion are wider than this and apply to other situations too.

Capacitively coupled interference (see Fig.6.1a) can be reduced using screening, which effectively grounds the interference coupling capacitance (Fig.6.1b). Screening

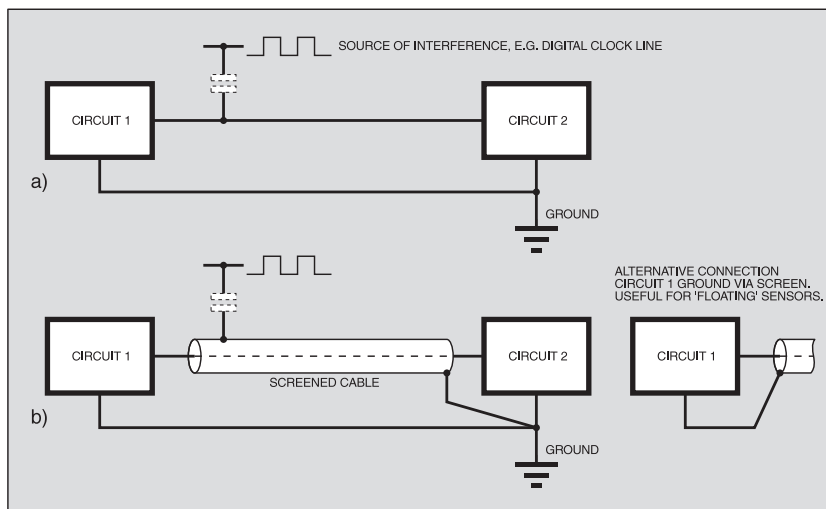


Fig.6.1. Capacitively coupled interference (a), and the use of screening to inhibit it (b).

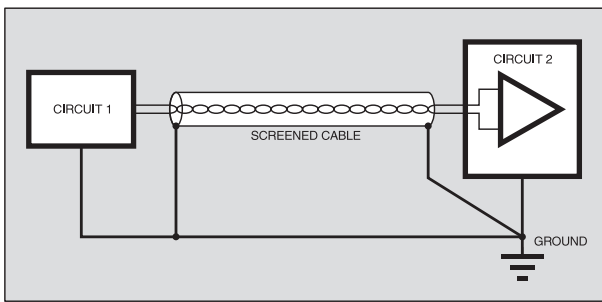


Fig.6.2 (above). Screened differential signal.

Fig.6.3 (right). Large wiring loops (a) make a circuit susceptible to voltages generated by magnetic fields. Reducing loop size (b) helps to combat the problem.

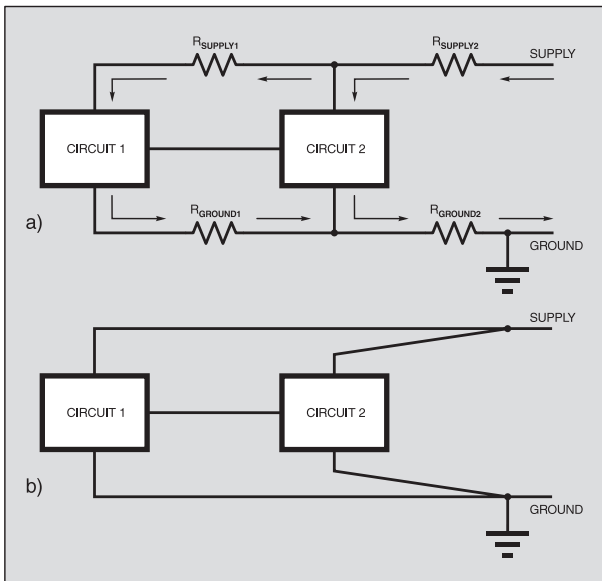
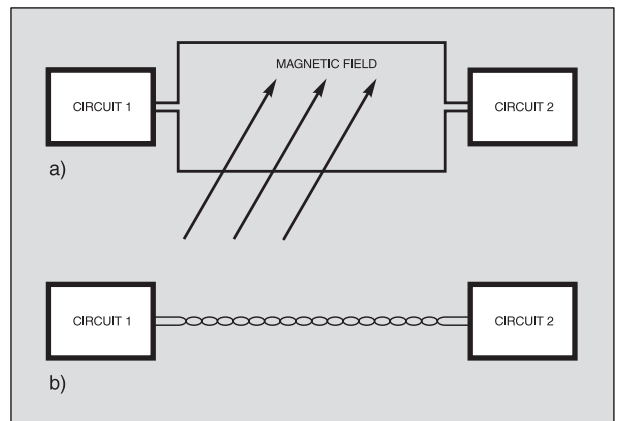


Fig.6.4. Voltage drops in the supply line (a) caused by the line's inherent resistance can be reduced by point-to-point wiring (b).

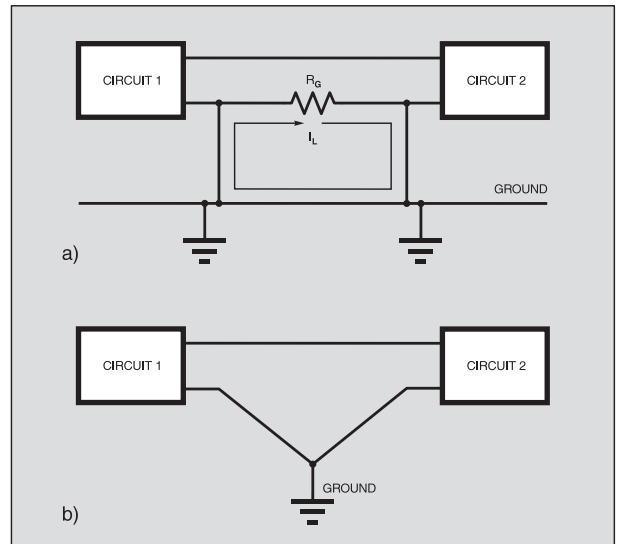


Fig.6.5. Ground loops between circuits (a) can be avoided by using a single ground connection.

is implemented using coaxial (screened) cable to link (for example) a sensor to a circuit, and by enclosing the sensitive circuits in a grounded screening box.

The source of interference can also be screened to reduce its effect on other circuits. Choice of where the screened cable is grounded may have an effect on circuit performance due to the possibility of creating grounding loops if the screen/signal return path is grounded at both ends (more on this a little later).

For differential signals we can also use screened wires – the two signal wires form a twisted pair and are enclosed by the screen (see Fig.6.2). Here grounding at both ends is not a problem as the ground does not carry the signal.

Magnetic interference is worse when physically large loops occur in the circuit (e.g. see Fig.6.3a) and can therefore be reduced by avoiding such loops – for cables, the use of twisted pairs of wires is an effective approach (e.g. see Fig.6.3b). For circuit boards, use a “ground plane” on one side of the board. For ribbon cables, make sure each signal has an adjacent return wire.

Circuits can be shielded against magnetic fields, but this is not used as commonly as shielding for capacitive coupling as it

requires special high permeability materials such as Mu-Metal. These materials are expensive and as they may need to be quite thick the screening may be bulky.

Supply Based Interference. The circuit in Fig.6.4 illustrates how supply resistance (Fig.6.4a) may lead to errors or interference. The supply current taken by a circuit causes a voltage drop across the supply wiring, so for example, the “ground” voltage at each sub-circuit will not actually be at 0V.

This will obviously cause problems if we are trying to make accurate voltage measurements (with reference to ground). The error in the ground voltage is not necessarily constant; as the supply current of one sub-circuit varies then the supply voltage drop and hence the ground error voltage at this and other sub-circuits fluctuates (this is sometimes called **ground bounce**).

This problem can be very significant, for example, when one sub-circuit has a digital clock signal that is coupled via the supply into a sensitive amplifier. The solution is to wire the supply and ground connections separately to a single point rather than using the same point-to-point wire for all the connections (see Fig.6.4b). This approach applies equally to the wiring inside the cabinet of an instrument and to

the supply connections on an integrated circuit.

Noise can also find its way from the a.c. power lines through your power supply and into your circuit. Power line noise can be quite substantial if your circuit is on the same mains connection as equipment such as cookers or power tools. A power line filter can help reduce power line noise.

GROUND LOOPS

When two circuits, sub-circuits, instruments, or other equipment, are grounded at two separate points on a “ground bus” we have a situation known as a **ground loop** (or **earth loop**) (see Fig.6.5a). The ground bus may be a circuit board track, the chassis of the equipment, point-to-point wiring, or most commonly the mains earth connected at different outlets.

This situation does not only occur in measurement and instrumentation systems, many people have suffered unnecessary levels of hum in their hi-fi systems due to earth loops!

The ground loop will pick up magnetic interference, probably mains-hum and may also act like an antenna picking up radio frequency interference. Large loops will make the problem worse. Ground loops are a particular problem when two or more

mains-powered systems (such as lab instruments and sensor circuits) are separately earthed and connected together.

The interference causes a current, I_L , to flow in the ground loop, which in turn causes an additional voltage drop ($I_L R_G$) across the resistance, R_G , of the ground connection between the equipment or sub-circuits.

The best solution to ground loops is to avoid them by using a single grounding point (Fig.6.5b). Use of differential signals, use of screening and use of very low resistance ground connections between circuits (reducing R_G) also help to minimise ground loop problems.

SIGNAL GUARDING

Signal guarding is concerned with getting the most out of screened cable connections, particularly when connecting very low-level signals from high impedance sources to high precision circuits. In such cases effects such as leakage currents in the cables and cable capacitance can cause significant errors.

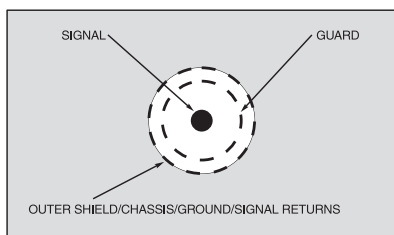


Fig.6.6. Triaxial connector use with triaxial cables for guarded connection.



Example of a triaxial connector.

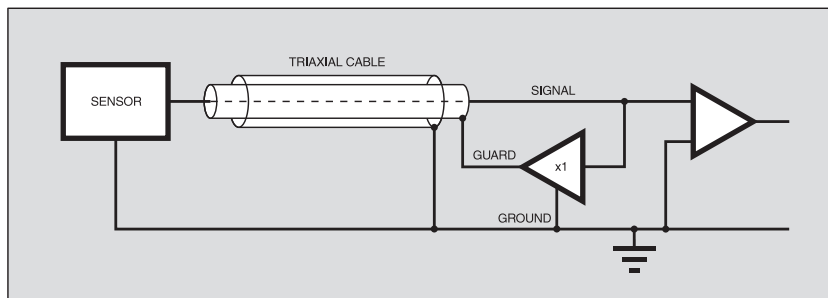


Fig.6.7. Guarded signal connection.

Signal guarding uses triaxial cables and connectors (see Fig.6.6), which have an inner conductor, carrying the signal of interest and two layers of shielding. The inner shield is connected to a signal of equal voltage to the signal provided by a unity gain amplifier (see Fig.6.7). This means that there is a zero voltage difference between the signal and inner shield so the leakage currents (and capacitance effects) are minimised. The outer shield is usually grounded and provides interference protection for the guard signal.

As an example of how guarding works consider the schematic in Fig.6.8a, for which an equivalent circuit is shown in Fig.6.8b. Here we are trying to measure the resistance of a sensor, R_S , which has a very high resistance value and therefore leakage through the cable insulation resistance R_C is significant.

We apply V_M and measure I_M – this should give the value of R_S as V_M/I_M , but actually gives us this parallel combination of R_S and R_C due to the leakage current I_L .

Using a guard (Figs.6.8c and 6.8d) means that the voltage across R_{C1} between the inner conductor and guard is zero and hence no leakage current flows. The buffer amplifier has no difficulty in supplying the guard-to-ground leakage current I_{L2} and this does not disrupt the measurement.

Differential signals can also be guarded by applying a buffered common-mode signal to the guard shield. Obviously the cable requires two central conductors for this purpose. How such a signal may be generated

from an instrumentation amplifier is shown in Fig.6.9. The two resistors with equal value R_5 provide the guard signal via the unity gain buffer. The exact value for R_5 is not too critical, about 10k Ω would be suitable. The other resistor values and general operation were discussed last month.

YET MORE TO WORRY ABOUT!

Sensor systems are also prone to a variety of forms of interference-based noise and errors other than electrically/magnetically coupled signals, including mechanical and electrochemical effects.

Movement and vibration of sensor cables can create electric current through the **triboelectric effect** – charges created due to friction between a conductor and an insulator. Low noise cables are available for situations where this may be a particular problem. Making sure that cables are well supported and not subject to vibration or large temperature fluctuations helps reduce this effect for any cable.

Movement can also generate unwanted signals through the **piezoelectric effect** (recently discussed in relation to sensors – Part 4, Feb '02), which occurs when mechanical stress is applied to insulators, and may also occur in the terminals used to connect input signals. Unwanted signals due to movement and mechanical stress are sometimes called **microphonic effects** because, if the signal is listened to, the movement of (for example) a cable will be audible.

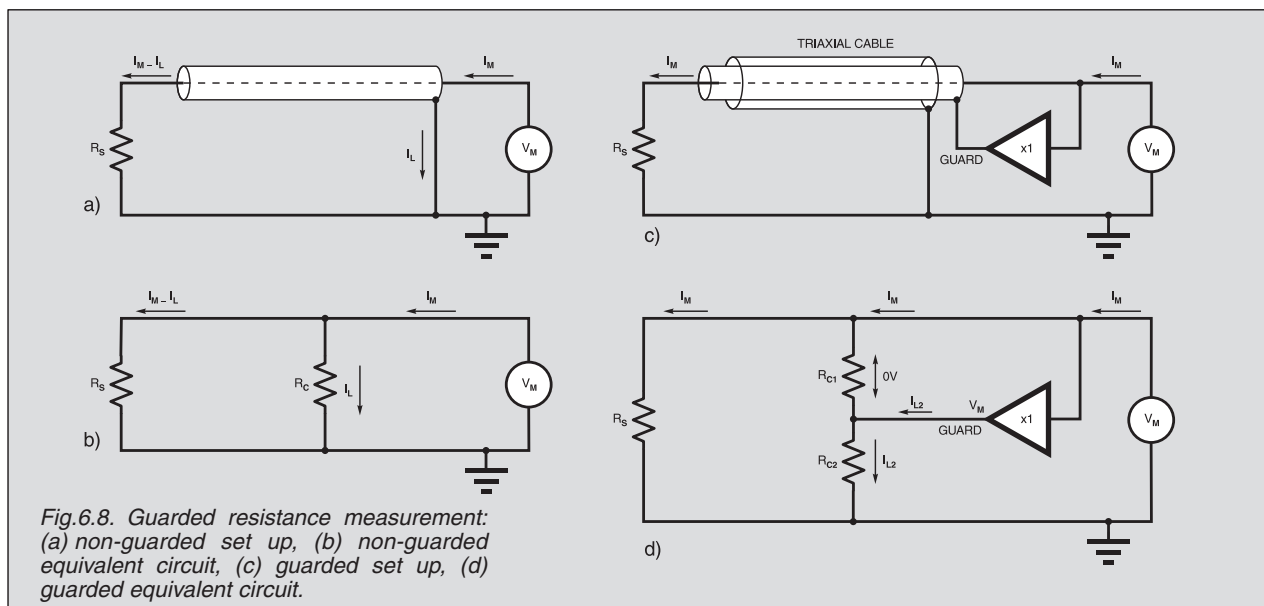


Fig.6.8. Guarded resistance measurement: (a) non-guarded set up, (b) non-guarded equivalent circuit, (c) guarded set up, (d) guarded equivalent circuit.

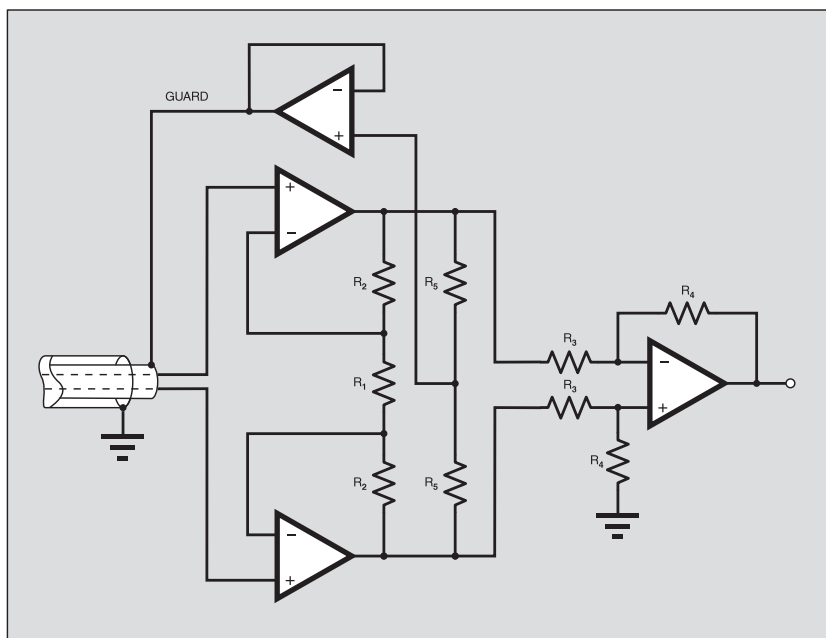


Fig.6.9. Guard signal for instrumentation amplifier.

Batteries create electric current through electrochemical effects. Similar processes can occur if contaminants are present on circuit boards and terminals. Variations in humidity can affect sensor systems with very high impedances. Contaminants (e.g. from handling cables and connectors) can also reduce insulation resistance leading to errors. High precision circuits and sensors must be kept clean!

RANDOM NOISE

The electronic components and sensors used to build circuits generate noise from within themselves that is random in nature. This means that we can never predict the actual instantaneous value of the noise voltage (or current), although the overall statistics of how the noise behaves is known, however.

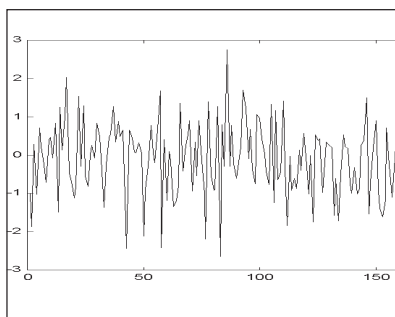


Fig.6.10. Example of random noise, illustrated via the Picoscope.

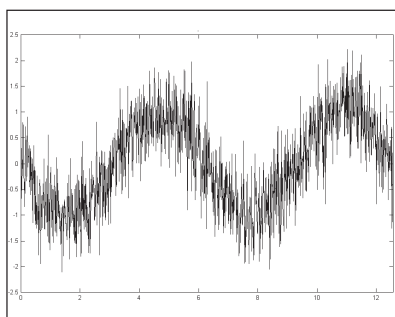


Fig.6.11. Picoscope display of a sine wave heavily contaminated by noise.

A typical random noise signal is shown in Fig.6.10. A sine wave suffering from a significant amount of random noise is shown in Fig.6.11.

The fact that the components in any electronic circuit or system generate random noise means that there is always a certain level of noise, even with no signal present. This is known as the **noise floor**, which is important because the circuit cannot meaningfully process sensor signals that are smaller than the noise floor.

As the noise floor relates to noise *within the circuit*, this is different from noise *within the input signal*. If the properties of the required signal are known, there are techniques which can extract signals that are smaller than noise present *within the signal*, for example, due to interference.

The random noise generated within electronic components and sensors is fundamentally due to the discrete nature of electricity at the atomic level, i.e. electric charge in circuits is carried in packets of fixed size on electrons. Random noise may be classed according to the frequency, or range of frequencies present. **White noise** has the same power throughout the frequency spectrum, whereas **1/f noise** (or **pink noise**) decreases in proportion to frequency.

For 1/f noise there is the same amount of noise power in the bandwidth of say 100Hz to 1kHz as there is in 1kHz to 10kHz, whereas for white noise there would be 10 times as much power in the bandwidth 1kHz to 10kHz as 100Hz to 1kHz because it is 10 times larger.

The difference between the signal and the noise is often of great importance. This is expressed as the **signal-to-noise ratio** (SNR), usually in decibels (dB) and based on the ratio of noise *power* (hence the v^2 terms in the equation).

$$SNR = 10 \log_{10} \left(\frac{v_s^2}{v_n^2} \right)$$

Where v_s is the r.m.s. signal voltage and v_n is the r.m.s. noise voltage. When using or quoting SNR values the bandwidth (range of signal and noise frequencies considered)

should be quoted because noise power is frequency dependent and noise may be present well outside the range of signal frequencies of interest.

Next month we will continue to look at random noise, meanwhile let us turn our attention to magnetic sensors.

REED SWITCHES

The simplest magnetic sensor is the **reed switch**, which usually consists of two contacts made of ferrous metal housed in a sealed glass tube. For most reed switches the contacts are usually open but, when a magnet is brought sufficiently close the two strips of metal become magnetized and will attract each other, closing the switch.



Typical example of a reed switch.

Such a simple device has many applications, ranging from detecting when doors open and close to detecting the rate of rotation of an object such as an axle. In the first case, the switch is placed on the wall close to the door, while in the second case the magnet is placed on the axle and causes the reed switch to periodically close as the axle rotates. We will be using this approach to measure wind speed in *Lab Work*, where the sensor will be a Hall effect sensor instead of a reed switch.

BOUNCY SWITCHES

One major concern with reed switches (and all switches) is **switch bounce** that occurs when a switch is closed – because the switch contacts are springy, they will bounce open and closed for several milliseconds before remaining closed. This may be OK for turning lights on and off but causes problems if we wish to connect a switch to a logic circuit.

In Fig.6.12 is shown a screenshot of a reed switch bouncing, captured using the Picoscope. You can imagine a circuit designed to count the number of times a door is opened. The circuit is straightforward – a reed switch connected to the input of a counter device which may display the count value on l.e.d.s. Every time the switch is activated, it will bounce three or possible four times, causing the counter to count three or four times.

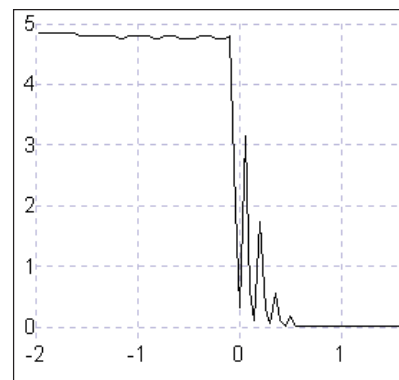


Fig.6.12. Picoscope display of switch bounce.

We need a **switch debouncing circuit** to stop this. Lab 6.1 illustrates switch bounce using reed switches and Lab 6.2 shows how we can use a switch debouncing circuit to overcome this. You can use these circuits to debounce any switch. If switches are connected directly to the input of a microcontroller, then we can design software to provide debounce instead of hardware.

SEMICONDUCTING SENSORS

Semiconducting magnetic sensors use the **Hall Effect** which was discovered by Edwin Hall in 1879. He was working on the effects of a magnetic field on current in a thin sheet of gold, when he noticed that a small voltage was generated at the edges of the sheet when the magnetic field was perpendicular to the foil. This effect occurs in all conductors but is strong in silicon and other semiconductors. Panel 6.1 gives an explanation of magnetic field and Panel 6.2 explains the Hall Effect.

As we can see from Panel 6.2, the voltage across a wafer of silicon is proportional to the product of the current flowing through the wafer and the applied magnetic field. Commercial Hall Effect devices can operate with magnetic fields from about 0.1mT to 1T (**tesla**). A strong permanent magnet has a field of about 1 tesla.

The tesla (T) is the SI unit of magnetic flux density and is related to **gauss** (the equivalent CGS unit, symbol G) by multiplying the value in mT by 10, i.e. 10mT = 100 gauss ($1\text{G} = 10^{-4}\text{T}$).

There are three types of Hall-effect device – *linear*, *unipolar* and *bipolar*. The linear device has an output voltage proportional to the magnetic flux density and is used in applications where the magnetic flux density is to be measured, e.g. for an electronic compass or for measuring current without contact.

Unipolar and bipolar sensors provide digital outputs. For example, a sensor may be “off” in the absence of a magnetic field and “on” when a field over a certain level is

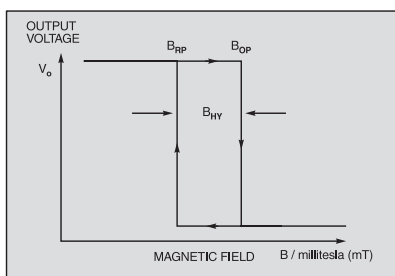


Fig.6.13. Output graph for a switching Hall effect device.

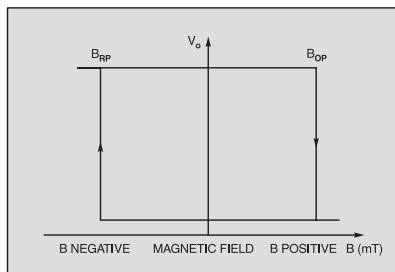


Fig.6.14. Output graph for a latching Hall effect device.

PANEL 6.1 Magnetic Fields

We can define a magnetic field as a region in which a magnetic force exists and is produced by movement of electric charges. A conductor carrying a current will produce a magnetic field (Fig.6.15). Permanent magnets are different in that the magnetic fields of their atoms are lined up; this is in contrast to most materials where the magnetic fields are random.

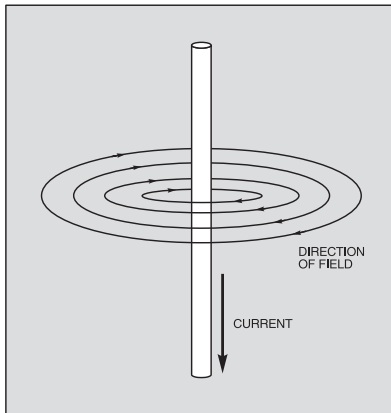


Fig.6.15. Current to magnetic field relationship.

Permanent magnets are made of iron or ferrite but stronger magnetic fields can be obtained using Neodymium Iron Boron (NiB) Samarium Cobalt (SmCo), Aluminum Nickel Cobalt (AlNiCo) alloys.

Magnets have north and south poles and we all know that like poles repel while opposites attract. The magnetic field is visualized as lines of flux that indicate the direction of the field and in the SI system is measured in **webers** (Wb), which is the field strength

multiplied by the area through which the field passes.

The **tesla** (T) is the SI unit of magnetic flux density equal to one weber per square metre, or 10^4 gauss. Finally, the **gauss** (G) is an older measure of flux density. The Earth's magnetic field varies with locality but is approximately 0.6G at the poles and 0.3G at the equator.

We sometimes need to know the force exerted by a magnetic field given the directions of movement of a charge and the magnetic field's direction. It turns out that they are all perpendicular to each other and can be remembered by **Fleming's Right Hand Rule**. If you hold your right hand as shown in Fig.6.16, then your thumb points in the direction of charge motion, the fore finger represents the direction of magnetic lines of force (from the north pole to the south pole) and the middle finger represents the direction of conventional current flow (positive to negative).

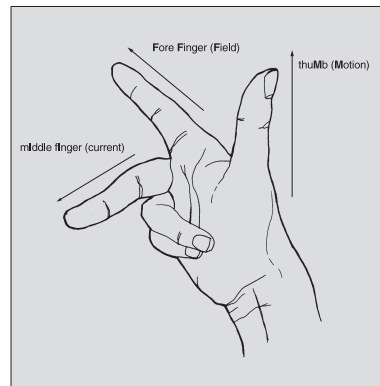
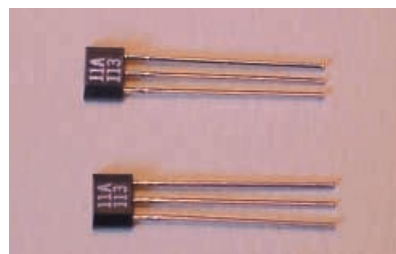


Fig.6.16. Fleming's Right Hand Rule.

<http://content.honeywell.com:80/sensing/prodinfo/solidstate/catalog/c20008.pdf> or just generally search via <http://content.honeywell.com>

These 3-pin sensors operate over a very wide supply range from 3-8V to 30V and are temperature compensated. Since they have a current switching output, they need a suitable resistor connected from the output to the supply. In Lab Work, we use a 470Ω resistor connected to an I.e.d. to illustrate their operation. The resistor can be any suitable value as long as the operating current (20mA) is not exceeded.



Examples of Hall effect switching devices.

present. Unipolar devices have an output voltage-to-magnetic field relationship as indicated in Fig.6.13, showing hysteresis where the operating point B_{OP} is different from the release point B_{RP} . The amount of hysteresis depends on the device chosen and provides a clean switching characteristic for the output.

Note that B_{OP} and B_{RP} are both positive, indicating that the device will switch “on” in the *presence* of a field (as opposed to its *absence*).

A bipolar device is different and will turn “on” in the presence of a positive field and “off” in the presence of a negative field as shown in Fig.6.14. Its output will only change state when the field is reversed and acts like a normal on-off switch and, once activated, will not change state even when the field is removed.

UNIPOLAR AND BIPOLAR

There are a number of unipolar and bipolar Hall-effect sensors available, the most common are from Honeywell and the characteristics of the SS400 series are given in Table 6.1. We will use two of these devices in Labs 6.1 and 6.2 to act as simple switches. Data sheets for the SS400 series can be downloaded from the Honeywell web site:

One other thing to be noticed from Table 6.1 is that they have a very fast switching time, 1.5µs or faster, which means they can detect rapid changes in magnetic field.

Applications of bipolar sensors range from simple detection of the presence of a magnetic field and sensing doors opening and closing, to measurement of rotation. We will be looking at their use in rotation sensing in Lab 6.5.

LINEAR SENSORS

Linear sensors produce an output proportional to the magnetic field and the Honeywell SS490 series is a good example. The SS495A operates from 5V to 10V and produces an output at 3-125mV per G with a range of -600G to +600G. More complex linear devices exist which have two axes perpendicular to each other; these can measure direction of magnetic field and can be used for electronic compasses.

Honeywell have several highly sensitive devices (e.g. the HMC1022) which are magnetoresistive and made of a Permalloy (nickel-iron) thin film deposited on a silicon wafer and patterned as four resistors in a bridge format. The presence of a magnetic field causes the resistance to change. We have already used bridges in previous circuits and they can be used for these sensors.

These sensors also have an offset strap which is used to cancel out any pre-existing magnetic fields. For example, suppose we are designing an electronic compass for use in a car. The car is made of ferrous metal which has a significant effect on the magnetic field inside the vehicle. If the compass is fixed in the car, then the magnetic field effect is approximated by a shift in the Earth's magnetic field and if this shift can be determined, it can be cancelled.

The offset strap is used to perform this task and it requires a high current to set or reset its magnetic field. As you can imagine, this makes the circuitry more complex and in some applications the circuit includes feedback from the sensor to control the strap in order to minimise ambient fields. We will not be going into this, partly because of the complexity of the circuits but mainly because the sensors are very expensive.

PANEL 6.2 Hall Effect

The illustration in Fig.6.17 shows a thin wafer of semiconductor, thickness *d* with current *I_X* flowing in the *X* direction, an applied magnetic field *B_Y* in the *Y* direction and a voltage *E_Z* generated in the *Z* direction across the wafer. The size of the voltage is proportional to the product of the magnetic flux density and the current. If we consider how current flows in a semiconductor (it is made up of charge carriers, electrons and holes), the current *I_X* is given by:

$I_X = nqvA$

Where:

n = number of charge carriers per unit volume

A = cross-sectional area of the wafer

q = charge on an electron

v = average velocity of the charge carriers through the wafer

If we apply a magnetic field, *B_Y*, the charge carriers experience a force causing the carriers to move towards one side of the wafer (e.g. the top), leaving a deficit on the other side. This creates an electric field *E_Z* which creates another force on the carriers which

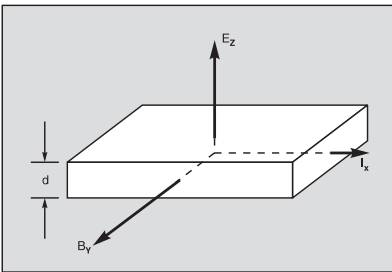


Fig.6.17. The Hall effect principle.

opposes the force caused by the magnetic field.

An equilibrium occurs when these two forces are equal; i.e. the force due to the electric field, *F_E* = *E_Z**q* and the force due to the magnetic field, *F_B* = *B_Y**qv*; so *E_Z* = *B_Y**v*. The resulting voltage (*V*) is:

$V = E_Z d$
 $= B_Y v d$
 $= B_Y I_X d / nqA$

where *d* is the thickness of the wafer.

In other words, *V* is proportional to *B_Y**I_X*.

Table 6.1. Honeywell SS400 Series of Digital Hall Effect Sensors

Type	SS411A Bipolar	SS413A Bipolar	SS441A Unipolar	SS443A Unipolar	SS449A Unipolar
Supply Voltage	3-8V to 30V	3-8V to 30V	3-8V to 30V	3-8V to 30V	3-8V to 30V
Max. Supply Current	10mA	10mA	10mA	10mA	10mA
Max. Output Voltage	0-40V	0-40V	0-40V	0-40V	0-40V
Max. Output Current	20mA	20mA	20mA	20mA	20mA
Output Switching Time (Risetime)	0-05µs typ. 1-5µs max.	0-05µs typ. 1-5µs max.	0-05µs typ. 1-5µs max.	0-05µs typ. 1-5µs max.	0-05µs typ. 1-5µs max.
Output Switching Time (Falltime)	0-15µs typ. 1-5µs max.	0-15µs typ. 1-5µs max.	0-15µs typ. 1-5µs max.	0-15µs typ. 1-5µs max.	0-15µs typ. 1-5µs max.
	(V _{cc} =12V, R=1.6k)				
Max.Operating Field	6-0mT	14-0mT	11-5mT	18-0mT	39-0mT
Min. Release Field	-6-0mT	-14-0mT	2-0mT	7-5mT	23-5mT

TEACH-IN 2002 – Lab Work 6

DAVE CHESMORE

Magnetic Switch Experiments

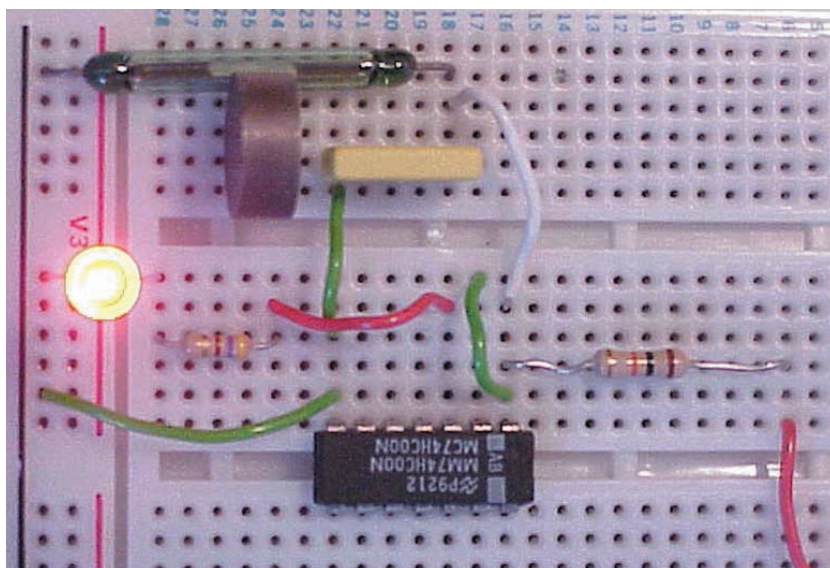
Lab 6.1 Reed Switch and Switch Bounce

In this Lab we illustrate the use of a reed switch, and how switch bounce can occur in its use. Construct the circuit in Fig.6.18 on your breadboard. The reed switch is connected between ground and 5V via resistor R1. The switch is also con-

nected across the input of a NAND gate (any gate will do, such as AND, OR, NOR, buffer or inverter, and could be from the 74xx or 40xx series).

Observe the switch's operation at input test point A, by connecting the Picoscope to the circuit and set to trigger on a negative sig-

nal, using the fastest timebase available. The Picoscope should capture the waveform when you bring a magnet close to the switch. You can capture a single trace if the trigger is set to once or repeat. The waveform should look like that in Fig.6.12 earlier, where you can see the bounce clearly.



Breadboard assembly for the circuit in Fig.6.18. Note the disk magnet alongside the reed switch.

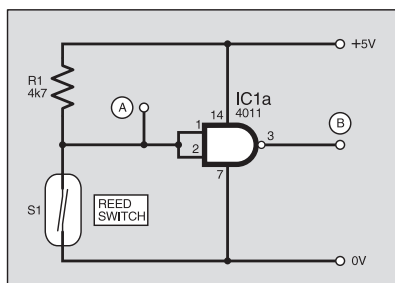


Fig.6.18. Reed switch and interface gate.

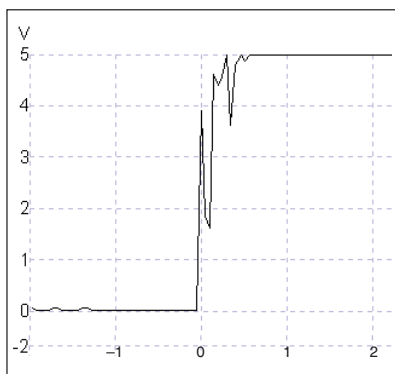


Fig.6.19. Switch bounce observed at point B in Fig.6.18.

Now observe the output of the gate (test point B). If you are using an inverting gate (as shown in Fig.6.18) then the trigger should be set to positive. Bring up the magnet and you should see the switch bounce converted to a short series of alternating logic levels before settling down, as shown in Fig.6.19.

Lab 6.2 Debouncing a Reed Switch

There are several ways of debouncing a switch. If you look in circuit books, you will most likely see the circuit in Fig.6.20 which uses a flip-flop to cause the output to change state when the switch is first closed. Any subsequent bounces will not cause the flip-flop to change state again. Note that this needs a changeover switch, which is

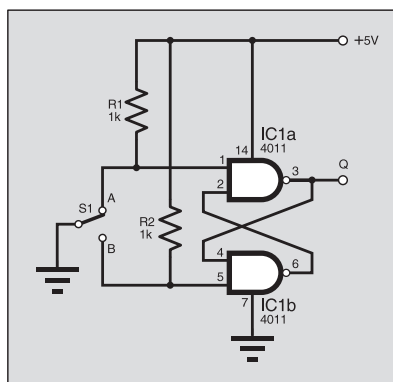


Fig.6.20. Switch debouncing flip-flop circuit.

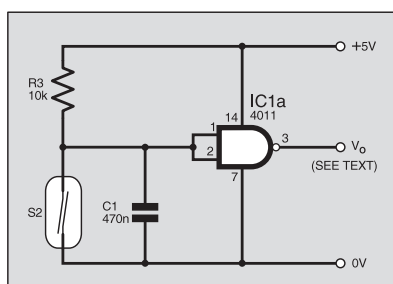


Fig.6.21. Simple switch debounce circuit. It is further improved if a Schmitt trigger gate is used.

not always practical. Most reed switches are not changeover although they can be purchased.

Another, simpler way of debouncing is shown in Fig.6.21 which uses a capacitor to effectively slow down the change in voltage to the input of the gate. In this case, the gate *must*, however, be a CMOS logic gate as we need a higher input impedance than a TTL gate provides. Also, using a Schmitt trigger gate (such as inverters 4106 or 4584) will improve matters because it shows hysteresis.

Selection of R3 and C1 is important, especially if we are going to activate the switch often, as may occur in a rotation

COMPONENTS

N.B. Some components are repeated between Lab Works.

Lab 6.1

Resistor			See SHOP TALK page
R1	4k7	0.25W	5% carbon film
Semiconductor			
IC1	4011 quad		NAND gate (see text)

Miscellaneous

S1	reed switch
----	-------------

Lab 6.2

Resistors

R1, R2	1k (2 off)
R3	10k
	0.25W 5% carbon film

Capacitor

C1	470n ceramic disc
----	-------------------

Semiconductor

IC1	4011 quad NAND gate (see text)
-----	--------------------------------

Miscellaneous

S1	s.p.d.t. min. toggle switch
S2	reed switch

Lab 6.3

Resistor

R1	470Ω 0.25W 5% carbon film
----	---------------------------

Semiconductors

D1	red l.e.d.
IC1	SS441 magnetic sensor

Miscellaneous

	Magnet (any type)
--	-------------------

Lab 6.4

Resistor

R1	470Ω 0.25W 5% carbon film
----	---------------------------

Semiconductors

D1	red l.e.d.
IC1	SS441 magnetic sensor

Lab 6.5

Resistors

R1	6k8
R2	120k
R3	470k
R4	1k5
	0.25W 5% carbon film

Potentiometer

VR1	10k min. preset
-----	-----------------

Capacitors

C1	1μ radial elect. 16V
C2	15μ radial elect. 16V

Semiconductors

IC1	SS441 magnetic sensor
IC2	4098 dual monostable
IC3	OP177 op.amp

Approx. Cost
Guidance Only

£5

sensor; this is because the combination of R3 and C1 acts as a low-pass filter which stops rapid changes – the larger the values of R3 and C1, the slower the circuit. We will be returning to the idea of filters in a later part of *Teach-In*.

The values chosen for Fig.6.21 are sufficient for our experiments but it is worth increasing the value of C1 by, say 10 times, to see the overall effect. Construct the circuit and observe the output of the gate as you did earlier. This time the output should be clean, without any bounces. If your switch is particularly bouncy then you may see one bounce – in this case, increase C1 until the bounce stops.

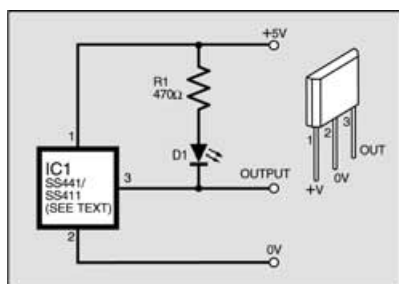
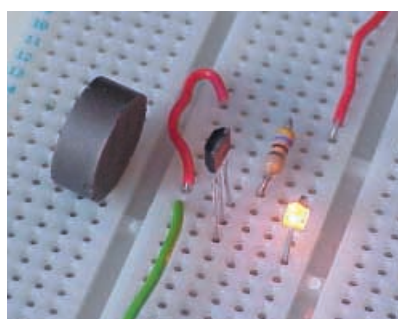


Fig.6.22. Circuit for Labs 6.3 and 6.4.



Breadboard assembly for the circuit in Fig.6.22, plus adjacent disk magnet.

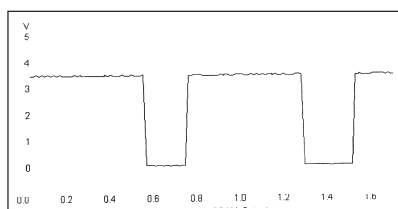
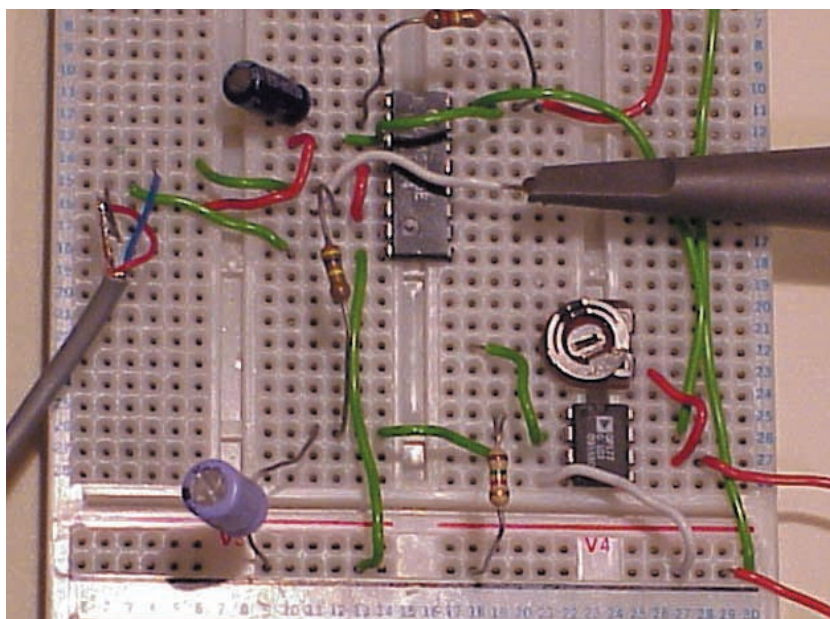
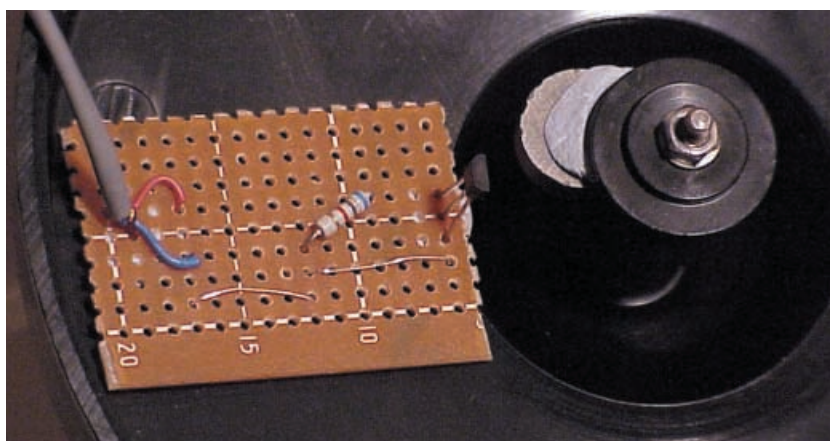


Fig.6.23. Cleanly switching output from the circuit in Fig.6.22.



Breadboard assembly for the circuit in Fig.6.24.



Rotational sensor used in Lab 6.5. It will be discussed more fully next month.

Lab 6.3 Unipolar Hall Effect Device

Connecting a SS441 switching sensor is very simple – it has three pins – supply, ground and output as shown in Fig.6.22.

The output is an *open-collector* type and needs to be connected to the power supply via a resistor (see the device's data sheet). We have added an l.e.d. to show when the output is "on" (sinking current).

Construct the circuit in Fig.6.22 and switch on. Bring a magnet close to the sensor and the l.e.d. should light. Monitor the output of the sensor using the Picoscope and capture the signal when the magnet is brought close. You should get an output similar to that in Fig.6.23, which shows a clean transition – no bounce!

A stronger magnet will cause the output to go on when it is further away. You can try this by magnetizing a screwdriver by stroking it in the same direction a number of times against a magnet – the more strokes, the stronger the magnet produced. Also test the circuit's response to a magnetic north pole being brought up to the front of the sensor and then the south pole.

Lab 6.4 Bipolar Hall Effect Device

Simply replace the switching sensor SS441 in Fig.6.22 with an SS411 latching sensor and try the same experiments as in Lab.6.1. The difference between a

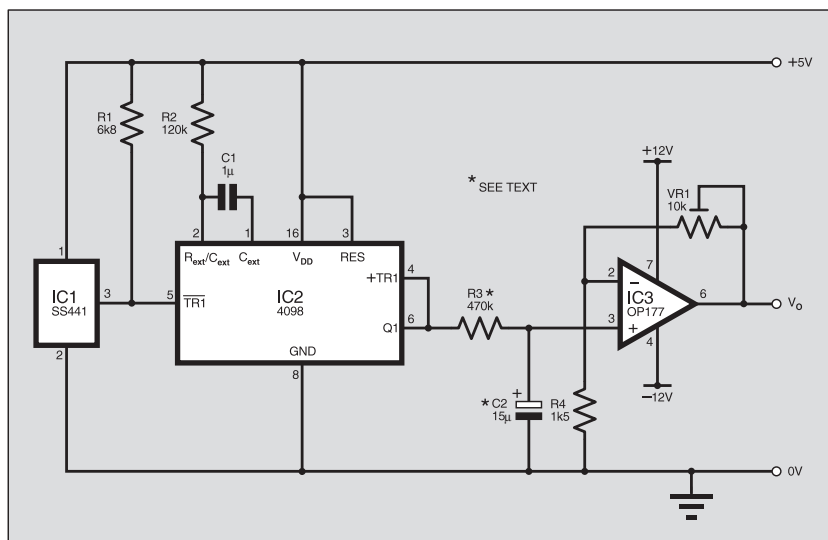


Fig.6.24. Simple rotational speed sensor circuit.

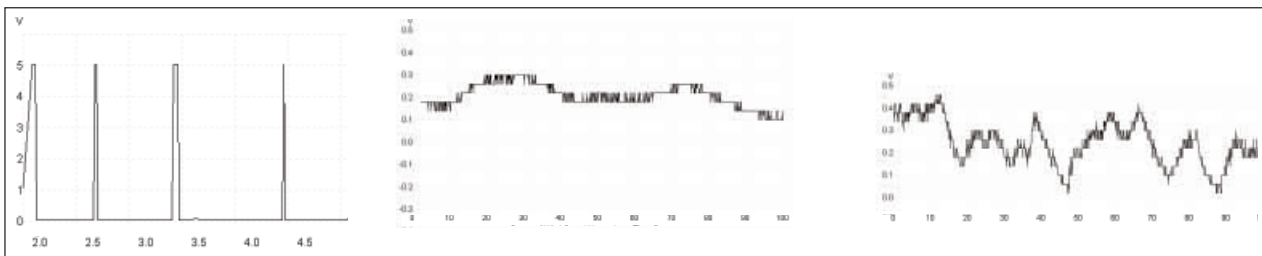


Fig.6.25. Waveforms monitored by the Picoscope with the circuit in Fig.6.24. Left: Pulse train from the output of the monostable (IC2) at pin 6. Centre: Varying wind speed monitored at the output of IC3, using long time-constant averaging. Right: As centre, using short time constant.



Anemometer assembly to be described next month.

switching and a latching sensor is that in a latching sensor the output will go on and stay on until a magnetic field of the opposite polarity is sensed.

Lab 6.5 Simple Rotation Sensor – Measuring Wind Speed

In this experiment, we will be building a very simple wind speed meter (anemometer) using an SS441 unipolar sensor and a magnet to detect the speed of rotation of a shaft. Note that we will be returning to this next month when we will be designing a higher quality combined wind speed and direction indicator.

This Lab illustrates the principle of

operation of rotation sensing and gives a very simple circuit to generate an analogue voltage proportional to speed of rotation. Fig.6.24 is the circuit for the sensor. It uses a frequency-to-voltage converter based on the humidity sensor in Part 3.

The wind speed sensor is shown in the accompanying photographs and consists of three cups attached to a shaft. Wind causes the cups to go round and the speed of rotation is proportional to wind speed. Don't worry about the design of the anemometer as we will be designing one next month. In the meantime, you can simulate the operation of the circuit using any shaft that can be rotated at a low speed (the turntable of a record deck, for instance).

The operation of the circuit is straightforward. The magnetic sensor (IC1) is placed close to the magnet, which is attached to the shaft, and its output is connected to the negative edge trigger input of a 4098 monostable (IC2).

The monostable is set up to be non-retriggerable, i.e. once triggered any subsequent negative edges at the input won't restart it until its time period has elapsed. The time constant is determined by the formula $0.5R2C1$ and is set to about 60ms. This value determines the highest speed that can be measured, in this case about 16 revolutions per second (16Hz).

The output of the monostable is passed into a low pass filter (R3, C2) whose average

output voltage is proportional to shaft speed. Finally, an OP177 op.amp (IC3) is used to amplify the output by up to seven times to produce a more usable voltage. Fig.6.25 shows typical waveforms generated.

There are a number of changes that can be made. Firstly, the time constant of the monostable determines the highest speed but if the pulses are narrow (high speed), then the energy added to the low-pass filter will be small so the output will be very low for low speeds.

Secondly, the value of the low-pass filter determines the response time – try changing the values and see what the effects are. Low values will give a fast response but you will see rapid decay between pulses. Conversely, large values will give a slow response and this can be seen if the shaft is suddenly stopped – the output will take some time to change.

NEXT MONTH

Next month we will look at how this simple anemometer can be improved. We also look at digital optical sensing, comparators, positioning and direction discrimination.

If you have any queries directly related to this series, you can write to the authors c/o the Editorial address, or you can email them to teach-in@epemag.demon.co.uk (no file attachments or general electronic queries please).

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02/02

INTERFACE

Robert Penfold



PC SERIAL PORT INTERFACING

READERS seem to send a steady flow of enquiries regarding the subject of PC serial interfacing. Many PCs have the parallel port occupied by a printer, PIC programmer, or some other gadget, but have one or both serial ports free for use with electronic projects.

On the face of it, the serial ports are then the obvious choice for interfacing your projects to the PC. In practice, however, the RS232C ports are not necessarily the best choice.

Interfacing to serial ports is less straightforward than using a parallel port, and the maximum rate for data transfers is much lower. Adding a parallel port card to the PC might be a better option. On the plus side, serial interfaces are designed for two-way operation, so independent 8-bit input and output ports can be provided by each serial interface.

Take Your PIC

Directly controlling the serial port hardware was covered not too long ago, in the October 1999 issue of *EPE*. Consequently, this aspect of serial interfacing will not be considered further here. The hardware side of serial interfacing has not been covered for some time, and it is the subject of this month's *Interface* article.

Many serial interface chips are designed for use on the buses of a microprocessor, making them unusable in simple add-on projects. For relatively simple projects a UART (universal asynchronous receiver/transmitter) is a more practical proposition.

The word format, etc., of a UART can be controlled by hard-wiring the control pins to the appropriate logic levels. This avoids the need to base projects on microprocessors, and enables the control logic to be kept as simple as possible.

PIC microcontrollers offer another means of interfacing to serial ports. In the past it was necessary to program the chip to provide the serial decoding, but some of the more recent PIC chips have a built-in UART. This greatly simplifies matters, and makes PIC chips well suited to "intelligent" serial port additions. This article will deal with the straightforward UART approach to serial interfacing, but the use of PIC chips in this role will be covered in a later article.

UART

The 6402 is the industry standard UART, and as such it is readily available. It has a 40-pin d.i.l. encapsulation and the pin assignments are shown in Fig.1. The transmitter and receiver sections are largely independent, and they can operate at different baud rates.

However, a common set of inputs determines the word format for both sections. This is not a major drawback, since practical applications would normally require a common word format. Pin 34 is taken high to load the control register with the bit pattern on pins 35 to 39. It can be pulsed high to latch momentary data into the control register, or simply held high if the control inputs are hard wired.

A wide range of formats are available, with from five to eight bits, one or two stop bits, and parity checking enabled or disable. All formats have the standard single start bit. The best format for general interfacing is eight data bits, one stop bit, and no parity checking.

Full eight-bit transfers are provided but the number of bits in each word is kept to a minimum. This format is obtained by taking pin 36 low and tying the other four control inputs high. There are separate clock inputs for the transmitter (pin 40) and the receiver (pin 17), but in most applications a single clock generator

drives them. The baud rate is one sixteenth of the clock frequency.

Grabbing Bytes

Received bytes are clocked into a shift register and then latched onto pins 5 to 12. The data on these lines therefore remains valid while the next byte of data is clocked into the shift register. This gives a "clean" switch from one byte of data to the next. The Data Received output (pin 19) goes high when a new byte of data is placed on the outputs, and this output is reset by briefly taking pin 18 low.

There are three error outputs associated with the receiver (pins 13 to 15), but these are of little use in the current context. The receiver outputs are all tristate types, but this ability is not normally needed unless the UART is interfaced to a microprocessor. Pins 4 and 16 are tied low to permanently enable the outputs.

The data to be transmitted is placed on pins 26 to 33, and pin 23 is then pulsed low to load the data into the transmitter buffer. The transmitter shift register is loaded immediately if it is empty. The byte of data is otherwise held in the transmitter buffer until the transmitter register is empty.

This method of buffering is normal with serial chips, and it is designed to reduce the risk of one byte being loaded before the previous one has been sent.

However, in order to avoid mishaps it is still necessary to ensure that the control logic operates effectively.

High Status

Status outputs at pins 22 and 24 respectively go high when the transmitter buffer register and the transmitter register are empty. One or other of these can be used to provide a hold-off until the relevant register is empty, or a clock circuit can control the transmission rate.

If the second option is chosen, the rate at which bytes are transmitted must be kept within the maximum that is supported by the baud rate in use. Dividing the baud rate by 10 gives the theoretical maximum for the number of bytes that can be transmitted per second.

At 19,200 baud for example, the theoretical maximum is 1,920 bytes per second, but in practice it would be advisable to settle for a slightly lower rate. A rate of about 1500 to 1600 bytes per second should give totally reliable results.

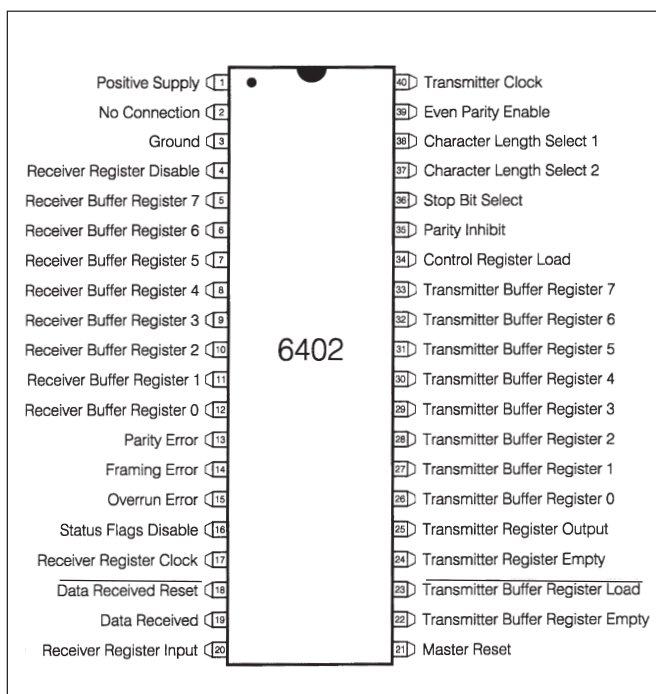


Fig.1. Pin assignments for the 6402 UART. The Receiver and Transmitter are largely independent.

Receiver Circuit

The circuit diagram for a Serial Receiver, based on the 6402 UART, is shown in Fig.2. The UART requires a relatively long reset pulse at switch-on, and capacitor C4 and resistor R6 provide this.

Serial interfaces do not operate at normal 5V logic levels, but instead use +12V to represent logic 0, and -12V to represent logic 1. A circuit that provides level shifting and an inversion must therefore precede the serial input of IC2.

There are special line receiver chips that can handle this task, but in this circuit a simple inverter stage based on transistor TR2 is used. Proper line receivers are preferable if the serial link must operate over long distances, but a simple inverter is perfectly adequate where short connecting cables are used.

A crystal controlled clock generator ensures that an accurate baud rate is obtained. Transistor TR1 is used in a simple crystal oscillator operating at 2.4576MHz, and this signal is divided by 8 in IC1. The 4024 is actually a seven stage binary counter, but in this circuit only three stages are used. This gives a clock frequency of 307.2kHz and a baud rate of 19,200. It is advisable to use a high baud rate in order to obtain a reasonably high maximum transfer rate, and 19200 is the highest standard baud rate.

In some applications it might be possible to avoid using any control logic. If the outputs are used to control lights, motors, etc., these will respond to changes in the output states as each new byte of data is received. In other applications it will be necessary for the main circuit to be triggered when fresh data is available for processing.

The Data Received output at pin 19 going high is then used to trigger the main circuit. Pin 18 must be pulsed low to reset this output before the next byte of data is received.

The eight outputs are at normal 5V CMOS logic levels, but in practice they seem to work well with 74LS devices in addition to 74HC and 4000 series CMOS chips. Although the 6402 UART is a complex device, its current consumption is very low at no more than a milliamp or two. The current consumption of the entire circuit is no more than about 4mA to 5mA.

Transmitter Circuit

The circuit diagram for a Serial Transmitter, based on the 6402, is shown in Fig.3. The clock and reset circuits are the same as those in the receiver.

If the UART is being used to send and receive data, the same reset and clock circuits are used for both sections of the device. The output signal at pin 9 of IC1 then connects to pins 17 and 40 of UART IC2.

A pulse is applied to the Send input in order to transmit a byte of data. This input is normally held high, and data is loaded into the transmitter buffer register on the high to low transition. Provided it is empty, the transmitter register is loaded on the low to high transition.

As explained previously, loading is delayed if this register is full, and data in the transmitter register will not be overwritten by new data. The same is not true of data in the buffer register, so it is essential not to feed the circuit with data at an excessive rate. The two status outputs of

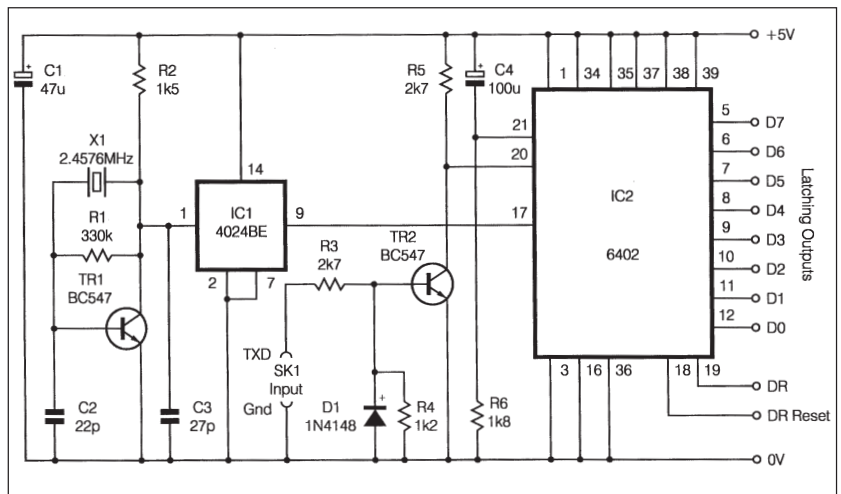


Fig.2. Circuit diagram for the Serial Receiver. This operates at 19,200 baud.

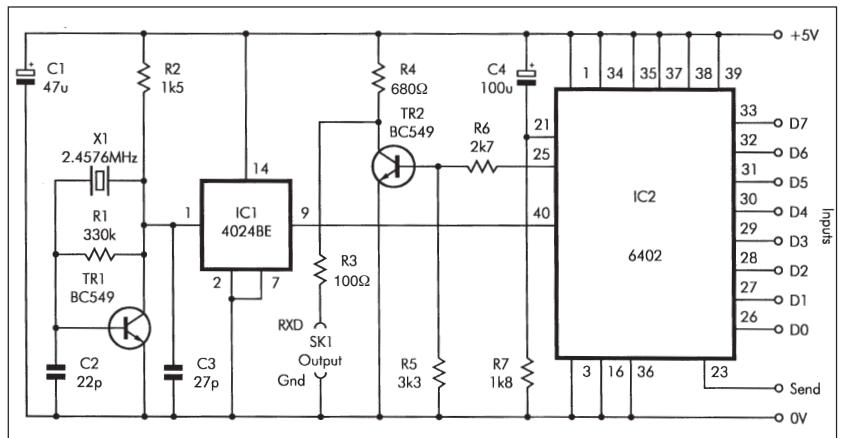


Fig.3. Circuit diagram for the Serial Transmitter. Pulsing the Send input results in a byte of data being transmitted.

IC2's transmitter section are available, should they be needed, but it is usually easier to have the control logic operating at a low enough speed to avoid any problems.

The serial output signal should be at nominal signal voltages of plus and minus 12V in order to guarantee that the circuit will drive the PC's serial port correctly. However, in practice most serial inputs will work reliably with normal 5V logic levels provided a short connecting cable is used. In this circuit transistor TR2 is used as a simple inverting buffer stage at the serial output of IC2.

There are special chips that make life easier if proper line drivers and receivers are needed. The circuit diagram of Fig.4 provides a simple line driver and a receiver, and the driver provides proper RS232C voltages. The circuit is powered from a single +5V supply, with the built-in switching power supply generating plus and minus 10V supplies for the line driver.

Handshaking?

Serial interfacing has a reputation for being awkward to implement, and one reason for this is the difficulties involved when handshaking is required. Fortunately, it should not be necessary to use handshaking when using a serial link to your projects. The relatively low

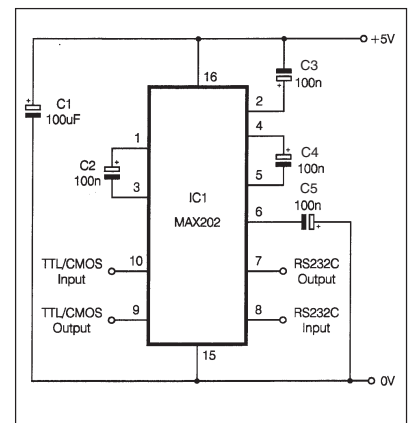


Fig.4. Circuit for a simple line driver and receiver using the MAX202.

speed of an RS232C port means that there is little risk of the add-on or the PC receiving data at a rate that it cannot handle.

However, you do have to be careful that data is not generated at a rate that is too high for the link to handle. Serial interfacing is not the right choice if high data transfer rates are needed. The interface's absolute maximum rate of 1,920 bytes per second must not be exceeded.

PIC CONTROLLED INTRUDER ALARM



JOHN BECKER

A sophisticated multi-zone intruder detection system that offers deluxe monitoring facilities.

WHEN Editor Mike suggested that the author might be interested in designing a PIC controlled intruder alarm, the suggestion was accepted in the knowledge that to do the job properly would make a worthwhile challenge.

The author has designed alarms before but none having the sophistication that appeared possible through using a PIC microcontroller. It seemed that an ideal system should have the features itemised in Panel 1.

It is believed that all the requirements listed in the Panel have been met in this design. How they are implemented will be discussed as we progress.

CONCEPTUAL LOGIC

Designing an intruder alarm system is based on the simple Boolean logic concept that a sensor's switch contacts can be either open or closed. If the contacts are found to be in the opposite condition to that in which they should be (e.g. open when they should be closed), then an alarm condition exists and appropriate action should be taken.

Everything else follows on from this logical argument but, as is illustrated through Panel 1, there are many factors that make a considerable difference between a 1-gate circuit that simply detects an open-closed condition and a system that provides a great many other security aiding facilities as well (there are around 1900 program commands in the controlling software for this design).

CIRCUIT DIAGRAM

The main circuit diagram for the PIC Controlled Intruder Alarm is shown in Fig.1. The principal functions are as follows:

Main Zones

PIC16F877 microcontroller IC1 is in charge of the entire system. Via port pins RD0-RD3 and RC0-RC3, which are used in input mode, the PIC can monitor between one and eight sensor zones, plus an extra "Panic" zone via RB4. The quantity is selected by the user and can be changed at any time. Zone detection will be discussed shortly.

Alarm Outputs

Four audio/visual alarm control outputs are provided, three via pins RE0-RE2, and one via RB5. When activated, these pins go high and are specifically intended for driving an internal buzzer (RE0), external strobe (RE1), external bell (RE2) and any device of the user's choice (RB5). As will be discussed in relation to Fig.3, the outputs can activate these devices (depending on their type) either directly, or via power transistors TR1 to TR4.

In any alarm condition, the bell, strobe (if fitted) and buzzer are all activated. The bell remains active for a period preset (and automatically stored) by the user through the software, with a maximum duration of 20 minutes. The software prevents the bell from restarting again, irrespective of further unauthorised zone entries (but see Panic Switches later).

Once activated, the alarm system can (normally – also see later) only be reset by keying in the correct PIN code.

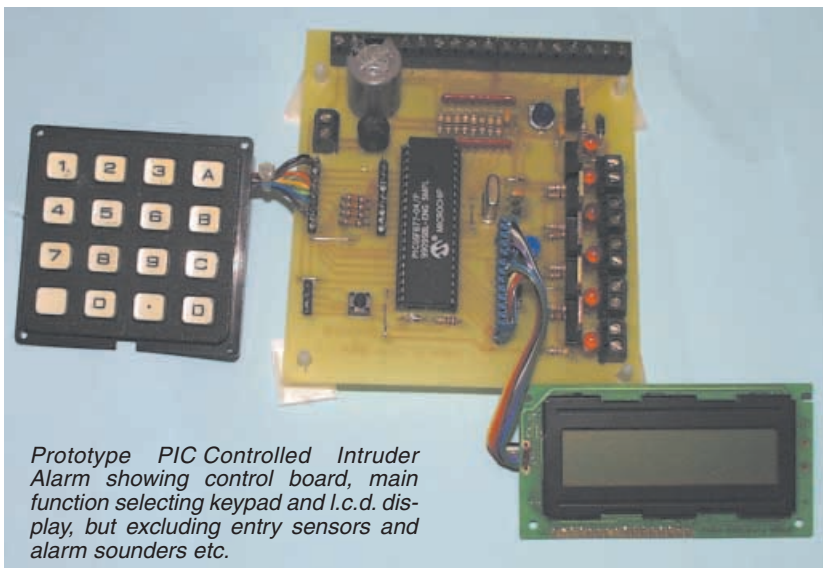
Display

A liquid crystal display (l.c.d.) module, X2, is controlled via pins RA0-RA5 operated in output mode. Pin RA4 is an open-collector output and is biased high to the +5V power line via resistor R2. The l.c.d. displays a variety of messages in respect of the several control and status modes that can be selected via the pushbutton keypad(s). It is used in conventional 4-bit control mode and its contrast is adjustable via preset VR1.

Keypad(s)

The main control of the system is accessed via a standard 16-key alphanumeric "data entry" keypad, S1, through which a unique 4-digit alphanumeric personal identity (PIN) code has to be keyed. There are 28560 permutations ($13^4 - 1$). The status of the keypad's pushbutton keys is monitored via port pins RC4-RC7 used in output mode, and RB0-RB3 used in input mode. Port B's internal "light pull-ups" are activated in the software and additional biasing resistors for RB0-RB3 are not needed.

Facilities for the use of an optional second 16-key keypad, S2, are provided, for reasons discussed later. Four of its pins share pins RC4-RC7 with keypad S1. The others are monitored by pins RD4-RD7 used in input mode, with logic-high biasing provided by resistors R3 to R6.



Prototype PIC Controlled Intruder Alarm showing control board, main function selecting keypad and l.c.d. display, but excluding entry sensors and alarm sounders etc.

PANEL 1: PIC Controlled Intruder Alarm Features

- Monitors between one and eight entry/exit points (zones) of a building or room
- Allows monitoring to be totally or partially suspended when required by the legitimate guardians (users) of the premises
- Indicates audibly (e.g. bell) and/or visibly (e.g. strobe) when one or more zones have been entered without authority
- Turns off activated bell after a preset period to prevent annoyance to neighbours
- Allows timed zone entry/exit (time-out) for users without triggering the full alarm
- Allows full monitoring of required zones once time-out has ended
- Allows users to terminate time-out procedure
- Allows users to control the monitoring system by means of a unique alphanumeric personal identity code (PIN) entered via a keypad
- Allows users to change the PIN code
- Allows users to access the control system without using a PIN code in the event of system failure or servicing
- Normally powered from a mains power source
- Instantaneously switches over to being powered by a heavy duty back-up battery if mains power fails
- Keeps the battery fully charged when mains power is present (the battery should be capable of keeping the monitoring system and any activated alarms operational for a reasonable period)
- Allows the system to resume active monitoring should power totally fail but subsequently resume
- Indicates that there has been a total power failure even after power has been resumed
- Prevents the bell from being activated when power is resumed
- Indicates for later viewing whether zones have been entered, even though there may also have been a power failure and resumption
- Allows monitoring of fewer zones than are available
- Automatically recognises whether a sensor should be monitored for an open circuit or a closed circuit
- Allows open circuit or closed circuit sensors to be used without system modification
- Recognises that a sensor is incorrectly open or closed prior to monitoring being activated and indicates which sensor is incorrect (i.e. door open when it should be closed)
- Allows users to preview zone sensor status
- Allows the bell-on time to be set for a shorter period than the 20 minutes permitted in the UK
- Prevents the bell-on time exceeding the UK limit
- Allows users to check the system by means of indicator lights without activating the bell (etc.)
- Allows indicator lights to display the status of the power supply and bell (etc.)
- Provides anti-tamper warning of interference with the system
- Provides a "Panic" button that immediately activates the bell (etc.) even if the system is not set for full zone monitoring
- Provides "passive" advice (e.g. buzzer) that a zone has been entered even if the system is not set for full monitoring, and for the advice to be terminated once the zone has been vacated (e.g. to monitor shop-door opening/closing)
- Accepts all conventional types of switched-output commercial sensor, including magnetic catches, pressure pads, passive infra-red (PIR) devices, vibration detectors, etc., and for any mixture of these to be used
- Provides an optional slave keypad with separate PIN for additional access to a selected zone
- Inherently stable and most unlikely to be triggered except via the installed sensors
- Inexpensive to construct

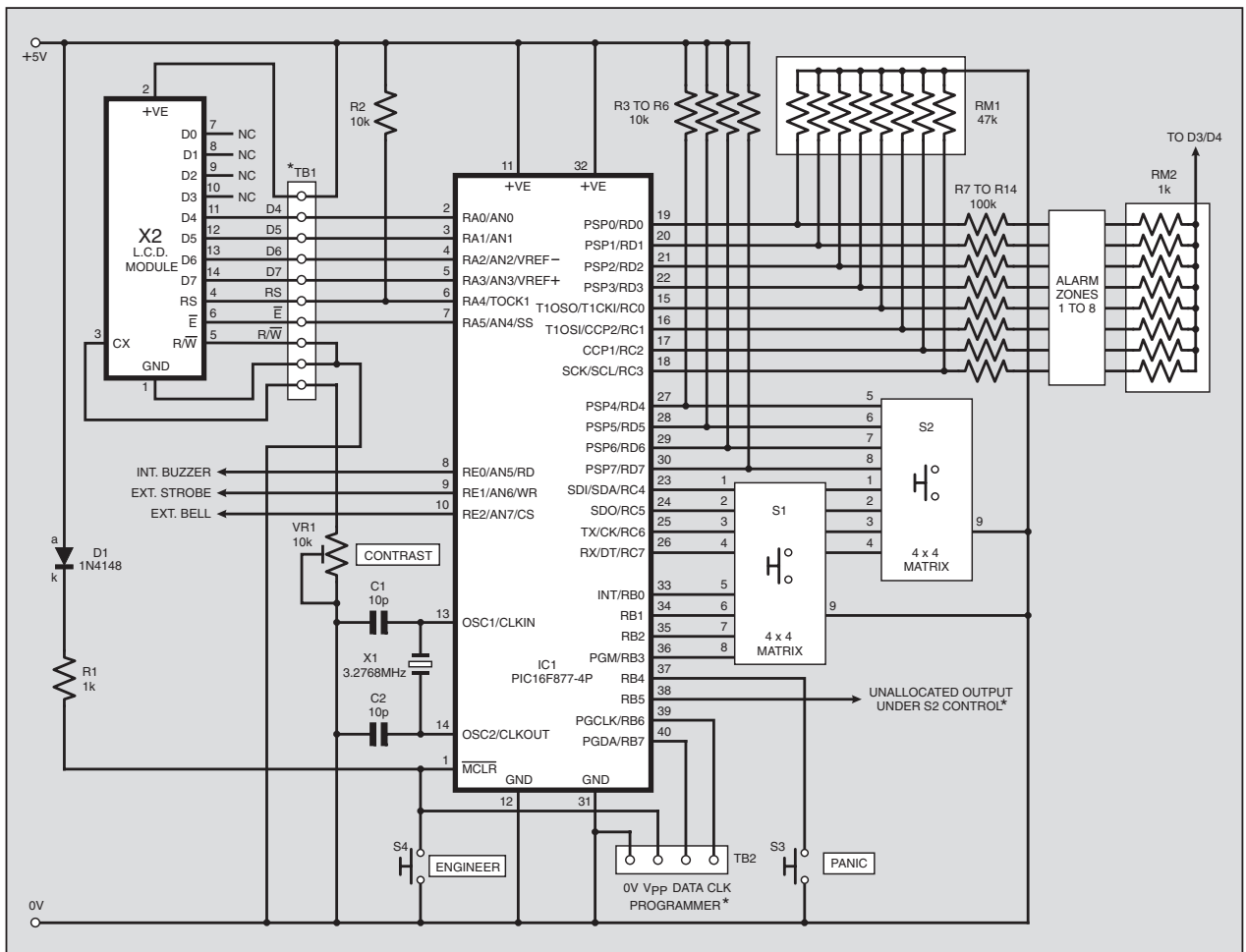


Fig.1. Main control unit for the PIC Controlled Intruder Alarm.

Immediate Panic

Port pin RB4 can be used as an alternative to using one of the eight main zones for "Panic" switch monitoring. The pin is used in input mode (internal pull-up activated) and when "Panic" switch S3 is pressed to short this pin to the 0V line, an "interrupt" is generated in the PIC and a flag is set.

In response to this flag, the software triggers the full alarm system, bell, strobe and buzzer (see Unauthorised Entry later). This occurs whether or not the rest of the alarm is in active or passive mode. The flag is then reset. The bell-on time is subject to the normal bell-on time-out, but also see later.

Timing

The PIC is operated at 3.2768MHz, as set by crystal X1. It is this rate which determines the accuracy of the software clock that controls the bell-on duration and entry/exit timing. In order to comply with the allocated timings, a different frequency *must not* be used with this design.

PIC Programming

During development, the author programmed the PIC via his *Toolkit TK3* system (Oct/Nov '01) and terminal block TB2. Resistor R1 and diode D1 allow correct operation of the MCLR pin during and after programming.

This facility may be used by those who wish to program their own PIC *in situ*. Pre-programmed PICs are available as stated later.

POWER SUPPLY

The design is intended to be mains powered with battery back-up. Referring to Fig.2, mains transformer T1 provides a 12V a.c. secondary output at about 1A. This is rectified by REC1 and smoothed by capacitors C3 and C4.

Light emitting diode (l.e.d.) D2, buffered by resistor R15, provides a power-on indication when a voltage of about 18V d.c. is present across C3. A mains input fuse is not used but could be included if preferred.

The raw d.c. voltage is fed to regulator IC2 whose nominal 12V d.c. output can be adjusted upwards by preset VR2. The intention is to set IC2's output voltage to the level that best suits the charging of the external 12V back-up battery, typically about 13.5V.

Current at the required voltage is fed to the back-up battery via diode D3, which prevents the battery from discharging back into IC2 during a mains power failure.

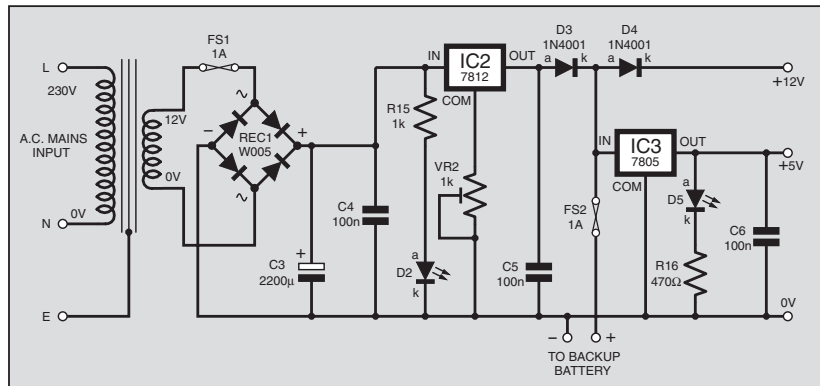


Fig.2. Power supply circuit diagram.

The voltage at the D3/battery junction is fed via diode D4 to provide approximately 12V d.c. to power external sensor and alarm warning devices, up to a total current of about 900mA (allowing a reasonable "headroom" for battery charging currents and that required by the control board).

Fuses FS1 and FS2 prevent transformer overload and battery discharging in the event of a short circuit between the 12V and 0V lines. It is recommended that panel mounting fuseholders are used.

The voltage at the D3/D4 junction is regulated down to +5V by IC3. This provides power for the PIC microcontroller IC1 and l.c.d. X2, neither of which must be powered at a higher voltage. The presence of an output voltage from IC3 is displayed by l.e.d. D5.

ALARM DEVICES

As previously said, there are four outputs through which the PIC can activate external alarm devices, either directly or indirectly, depending on their type.

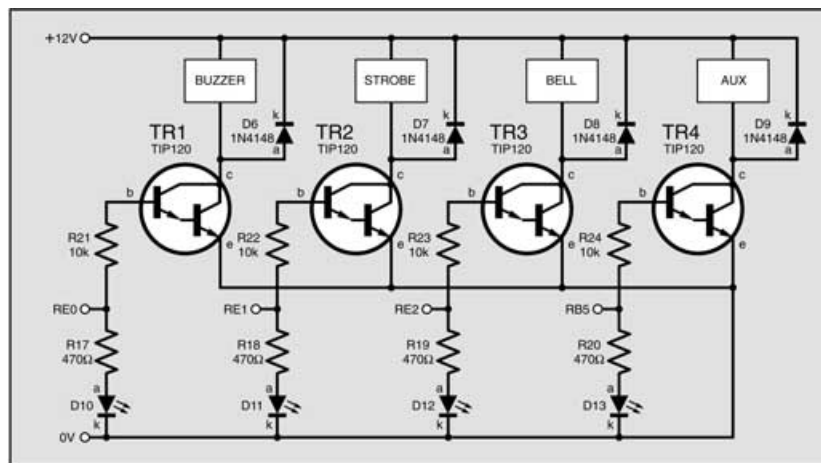


Fig.3. Circuit diagram for alarm output device drivers.

The PIC is capable of supply 25mA from each output pin, but it has a maximum *total* output current capability of 200mA (which must not be exceeded).

The 25mA current is capable of directly driving a warning buzzer, of the type that has its own in-built oscillator. It could also trigger alarm devices such as bells or strobes that have their own control circuit built in to them.

Most external devices, though, are likely to require driving at voltages and currents greater than the PIC can supply. For this reason, each of the RE0-RE2/RB5 outputs are connected to power-Darlington transistors, TR1 to TR4, as illustrated in

Fig.3. Each transistor is capable of sinking 1A sourced from the 12V d.c. power line, but remember that this line can only supply about 900mA, as said earlier.

Because of the way in which the software is written, external audio/visual alarm devices should only be connected in the order shown. The buzzer is frequently used to indicate a variety of functions, such as keypad presses, to indicate that entry/exit timing is in progress, and that an entry has been made if the "passive" mode is in operation.

The buzzer is also activated, along with the strobe and bell, in the event of an unauthorised intrusion being detected when the system is in full monitoring mode. The bell is automatically turned off after a preset delay via line RE2 and transistor TR3. The strobe and buzzer, though, remain active until an authorised user resets the alarm.

The auxiliary output option controlled via line RB5 is only activated for the maximum period that has been set for it, more later.

In addition to controlling their respective transistors (if installed), the four output lines each have an l.e.d./resistor pair. The l.e.d.s are turned on whenever the respective PIC line is high, regardless of whether a transistor is also connected to that output.

Each transistor has a diode connected between its collector and the 12V line. This is to inhibit back-e.m.f. pulses in the event that an inductive load is being driven via the transistor. It is permissible to control solenoids or relays.

INTRUSION DEFINITIONS

Returning to zone intrusion sensing via pins RD0-RD3 and RC0-RC3, refer to Fig.4.

This shows the equivalent circuits for the zone components when used with sensors that are normally-open or normally-closed. To clarify a possible source of confusion, the following definitions are used in this text:

Normally-open means any sensor which when in its normal required active state when monitoring an entry/exit point has its contacts in an *open* condition (see Fig.4a). Devices that work in this context of normally-open include pressure pads which require, for example, someone to tread on them in order to trigger the alarm system.

Normally-closed means any sensor which when in its normal required active state when monitoring an entry/exit point has its contacts in a *closed* condition (see Fig.4b).

Devices that work in this context of normally-closed include magnetically-operated switches secured either side of two adjacent sections on a door and its frame. The proximity of the magnet when the door is closed keeps the switch contacts closed. When the door is opened, the contacts open and so the alarm is triggered.

When ordering components for your alarm system it is important to understand these descriptions in relation to this design. Such terms have been known to create considerable confusion in the past. Hence our defining them now!

ZONE CIRCUIT LOGIC

In Fig.4, sensors are inserted into resistor networks as shown. In Fig.4a, with the sensor in a normally-open condition, the voltage at the junction of the 100k and 47k resistors is 0V, and monitored as such by the PIC.

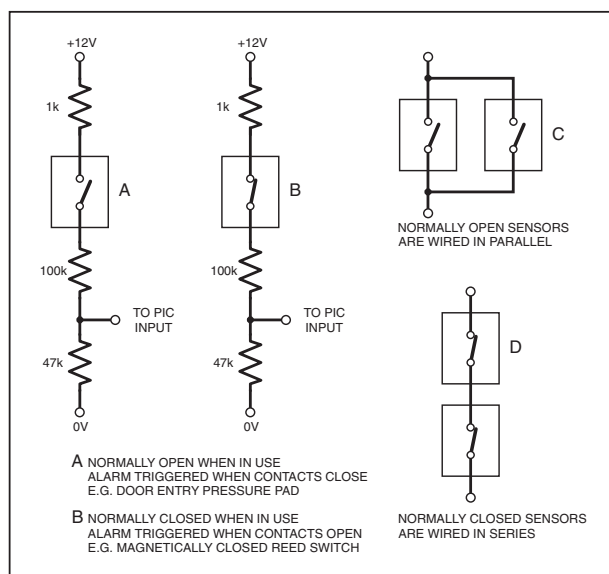


Fig.4. Zone intrusion sensor logic options.

If a zone is intruded, the sensor's contacts close and the voltage across the component series becomes the voltage at the output of diode D4, about 0.7V below that present at the battery, nominally 12V. The voltage actually fed to the PIC is that set by the potential divider values and will vary depending on the voltage across the divider.

Providing the input voltage is above 0.7V_{DD} ($5V \times 0.7 = 3.5V$), the PIC will recognise it as logic 1. The battery voltage can probably drop to as low as 10V and the PIC should still receive an input voltage recognisable as logic 1.

In Fig.4b, with the sensor in a normally-closed condition, the voltage at the junction of the 100k and 47k resistors is recognisable as logic 1 (see previous paragraph). If a zone is intruded, the sensor's contacts open and the voltage fed to the PIC falls to 0V.

The 1k resistor in the chain protects the 12V power line in the event of the sensor's cable being cut and shorted to 0V. It was felt to be unreasonable to attempt to protect the system against very high voltages being maliciously applied across sensor cables.

Several sensors may be used in each zone. For a normally-open zone they must

be wired in parallel (Fig.4c). For a normally-closed zone they must be wired in series (Fig.4d).

Do not mix normally-open and normally-closed sensors in the same zone.

KEYPADS

The first of the keypads, S1, is for keyed control of the total alarm system, including responding to a unique PIN code when keyed-in, rejecting any code that is not recognised.

Facilities for a second optional keypad, S2, have been included following a reader's request. During development of this alarm system, David Mynatt of Manchaca, Texas, emailed us to say that he wished to instal a system that would allow his (presumably responsible) children to let themselves into the house by use of a coded keypad or similar technique, and could we help.

After weighing up the various pros and cons, it was decided to include a second keypad with this controller which would be largely independent of the main system, but which would allow a PIN code to be keyed in and activate line RB5 and Darlington transistor TR4. As said earlier, the transistor can drive a load such as a relay or solenoid, consequently it could be used to activate an automatic door-latch, such as the type used in response to intercom requests at office or apartment premises, for example.

The PIN code required for keypad S2 is initially set via keypad S1 as part of the main system. In operation though, keying the correct PIN into S2 directly activates TR4. A countdown is started at that instant and TR4 remains on for a period which can be previously set as required via the main system. During this time the buzzer on line RE0/TR1 is also activated.

At the end of the preset period, the buzzer and TR4 are turned off again.

This secondary control is not tied into the main zone sensing system. If the secondary entry time-out period is not met, for example, the main alarm system is not triggered.

However, secondary entry could be made to tie in with the main system as well, by treating this entry zone as an alarm zone with its own separate sensor.

This would require, therefore, David Mynatt's children to enter their own PIN on keypad S2 (installed in a porch outside the main entry door, for example). This could cause the main latch to open, but once the door itself were open, would activate the countdown timing of the main system's "authorised entry" mode. The children would thus need to use the household's main PIN to deactivate the alarm within its allocated entry time.

It would be permissible, but perhaps unwise from a security point of view, to give the same PIN code to both keypads.

PANIC SWITCHES

As referred earlier, two options for "Panic" switches have been included. The first can be made using Zone 8, which is never allowed to be turned off through the software. A normally-open or normally-closed pushbutton switch can be used, mounted at a strategic location. When the switch is pressed, changing the status of its contacts, an alarm condition is sensed and the full bell, strobe, buzzer system is activated, as with other zones, with the bell still subject to time-out and non-retriggering.

The other option is via pin RB4. This is normally held high via its internal pull-up resistor. When normally-open pushswitch S3 is pressed, the pin is shorted to 0V. Again an alarm condition is sensed and acted upon. In this mode the bell is still subject to the preset time-out period, but can be reactivated if the Panic button is pressed again.

It seems reasonable that if someone really is in a "Panic" situation that they should be allowed to reactivate the bell at will.

Unlike the first option, this Panic mode is triggered whether or not the main alarm is in monitoring mode. The condition once triggered needs to be reset in the usual way.

Be aware, however, that this interrupt-driven option is potentially a weak link in the system's stability. All other alarm zone monitoring is done via software polling of the zones. Interrupts via RB4, though, are automatically generated by the PIC in response to any 0V-going change of logic status at this pin.

Whereas it is believed that the power supply and other zones are likely to be largely immune to external electrical interference (such as caused by electrical storms), an RB4 interrupt might conceivably be triggered under such conditions. Reader feedback on this would be welcomed.

If this Panic interrupt is not required, connect a link between the pins of the S3 connector, so holding RB4 permanently low.

CONSTRUCTION

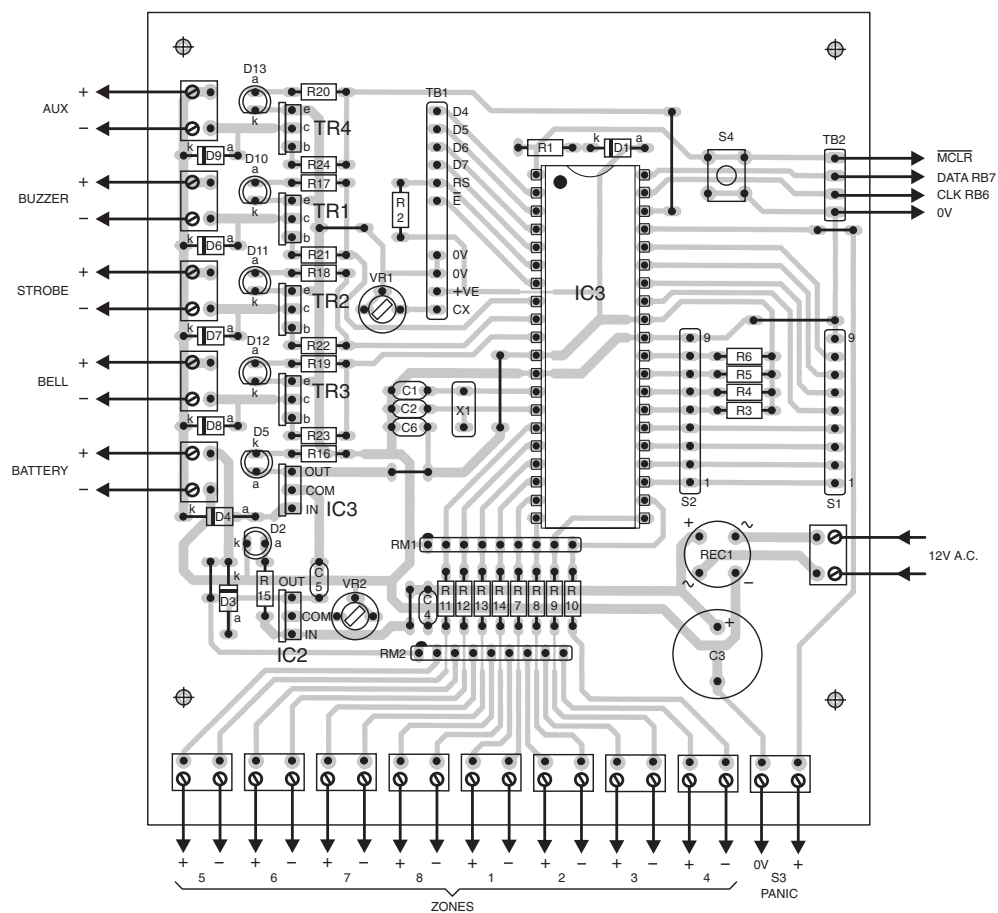
This design is mainly powered and its construction should only be undertaken by those who are suitably experienced or supervised.

Printed circuit board component and track layout details are shown in Fig.5. This board is available from the *EPE PCB Service*, code 339.

Assemble the components in order of size and use a socket for the PIC. Do not insert the PIC, or connect the l.c.d., until the correctness of the power supply has been confirmed.

It is not necessary to instal all the zone terminals shown. Just solder in those that are actually required. The system can be configured later in software (via keypad S1) to suit the entry zones you've decided to use.

Nor do you have to instal all output controlling transistors if their higher power capability or control functions are not needed (e.g. omission of the strobe or second keypad facility) – similarly with their terminal connectors. Note that the output



4-01N (101-6mm)

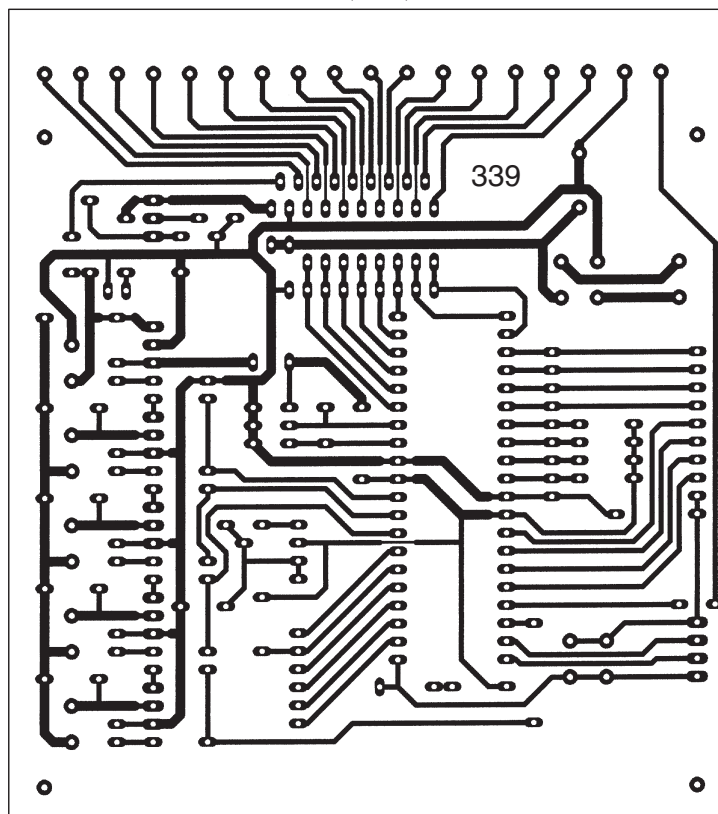
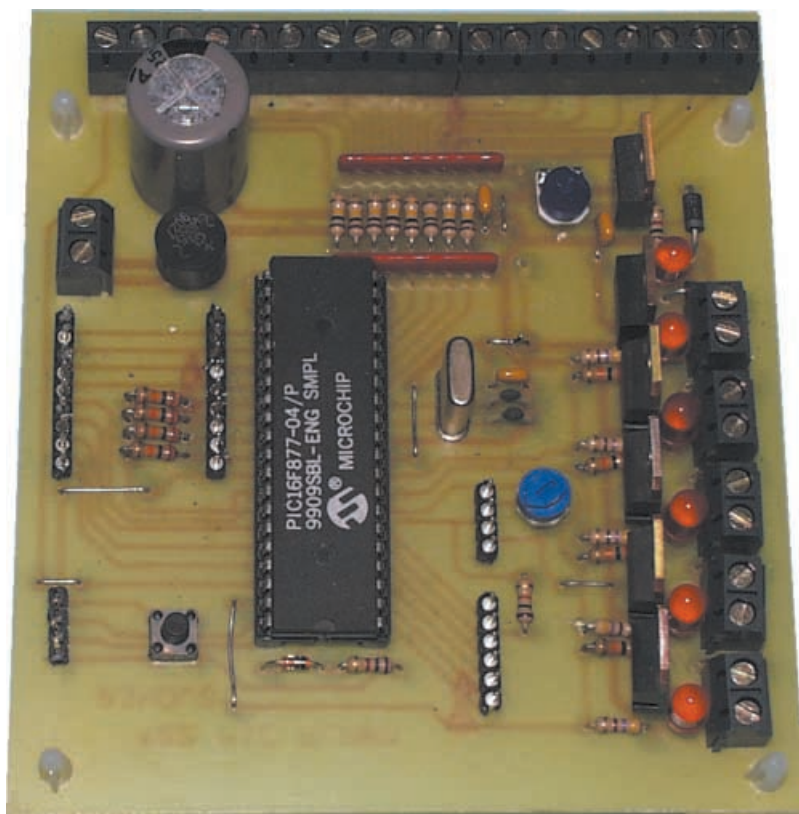


Fig.5. Printed circuit board component layout and full-size track master pattern.



COMPONENTS

Approx. Cost
Guidance Only
excluding case and alarm hardware

£35

Resistors

R1, R15,	1k (2 off)
R2 to R6,	
R21 to R24	10k (9 off)
R7 to R14	100k (8 off)
R16, R17	
to R20	470Ω (5 off)
RM1	8 x 47k common 9-pin s.i.l. resistor module
RM2	8 x 1k common 9-pin s.i.l. resistor module
(R1 to R24 0.25W 5% carbon film or better)	

Potentiometers

VR1	10k min. preset, round
VR2	1k min. preset, round

Capacitors

C1, C2	10p ceramic, 5mm pitch (2 off)
C3	2200μF radial elect, 25V
C4 to C6	100n ceramic, 5mm pitch (3 off)

Semiconductors

D1, D6	
to D9	1N4148 signal diode (5 off)
D2, D5,	
D10 to D13	red l.e.d. (6 off) (see text)
D3, D4	1N4001 rectifier diode (2 off)
REC1	W005 50V 1A bridge rectifier
TR1 to TR4	TIP120 npn Darlington transistor (4 off) (see text)
IC1	PIC16F877 microcontroller, pre-programmed (see text)
IC2	7812 +12V 1A voltage regulator
IC3	7805 +5V 1A voltage regulator

See
SHOP
TALK
page

Miscellaneous

S1, S2	16-key (4 x 4) data entry keypad (2 off, see text)
S3	push-to-make "Panic" switch, extra large, palm-activated, wall-mounting
S4	push-to-make switch, p.c.b. mounting, 0.2in pitch
FS1, FS2	1A fuse, slow-blow, with panel mounting holder (2 off)
T1	mains transformer, 12V secondary, 1A rating or higher
TB1	10-way pin-header strip, 0.1in pitch, 1mm dia.
TB2	4-way pin-header strip, 0.1in pitch, 1mm dia. (see text)
X1	3.2768MHz crystal
X2	2-line 16-character (per line) alphanumeric l.c.d. module

Printed circuit board, available from the *EPE PCB Service*, code 339; 40-pin d.i.l. socket; 2-way terminal blocks, p.c.b. mounting, side-by-side stacking, 0.2in pitch, screw connections (quantity to suit application, see text); metal or plastic case to suit application; 12V heavy-duty sealed lead-acid back-up battery; ribbon cable (9-way) for keypad(s) (see text); 9-pin pin-header strips and connectors, 0.1in pitch, 1mm dia. (2-off, optional, see text); p.c.b. supports (4 off); connecting wire; solder, etc.

Alarm fittings

Intruder sensors, bell, strobe, buzzer, types as required to suit application, 2-way or 4-way alarm cable (see text)

control logic is inverted if the transistors are not used. If the buzzer is to be used, TR1 must be installed.

The l.e.d.s and their ballast resistors can also be omitted as you see fit, although they do offer a useful monitoring facility if you need to troubleshoot the circuit at any time.

Whilst it is not necessary to fit link wires between unrequired zone terminal/track pairs, it is preferable to retain all zone 0V biasing via resistor module RM1. This will help to provide electrical stability to the PIC's unused inputs.

If "Panic" mode detection via RB4 is not needed, wire this pin to the 0V line to keep it stable.

It is suggested that the keypad(s) should be connected via ribbon cable and suitable 9-pin connectors to match their terminal pins and those on the board. A rear view of the keypad pinouts is shown in Fig.6.

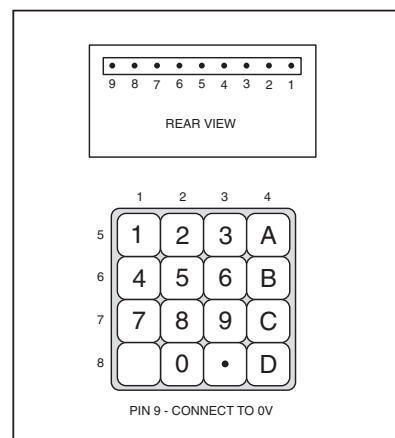


Fig.6. Rear view of keypad connections, plus keypad legends.

It is recognised that if the second keypad is also used, the cost of running 9-way ribbon cable from the unit across several metres to a door could be considerable. An alternative is to use two lengths of standard 4-way alarm system cable to make the connections for pins 1 to 8.

Pin 9 is simply for grounding the keypad's metal frame to earth and can possibly be ignored (but consider any possible mains electrical safety aspects first – any metal item that could potentially come into undesirable electrical contact with a mains supply *must* be earthed).

It would also be reasonable to use just four connections so that only four keys are active. The same degree of code security would remain since all 16 keys would still appear to be available.

TESTING

To assist bench testing, temporarily connect one or more switches to various zones to simulate sensors.

Fully check your p.c.b. assembly for errors and poor soldering before applying power. Do not connect mains power to the system until you have checked the rest of the system using a 12V battery (or bench power supply).

Connect the battery to the allocated terminals and check that +5V is present at the output of regulator IC3, and that around +11.4V is present at the cathode (k) of

diode D4 (i.e. about 0.6V below the battery's actual output voltage). L.E.D. D5 should be on.

If all is well, disconnect the battery. Connect the secondary winding of transformer T1 to the terminals provided. Set preset VR2 for minimum resistance between the common pin of regulator IC2 and the 0V line.

Ensuring satisfactory safety precautions are observed, connect mains power to the transformer. There should about +18V d.c. across the terminals of capacitor C3 and +12V at the output of IC2. Adjust VR2 until a voltage of about 13.5V (or the recharging voltage specified by the back-up battery manufacturer) is present across the battery terminal block pins.

Disconnect the mains power, insert the PIC, and reconnect the battery (which should be in a reasonably fully-charged state when first put into use). If the PIC has not been programmed yet, you can do this *in situ* now, using *Toolkit Mk2* or *Mk3* via connector TB2.

POWERING UP

When powering up with the programmed PIC in place, your first need is to adjust the I.c.d.'s screen contrast using preset VR1. Ignore any information which then becomes apparent – it depends on the existing contents of the PIC's data EEPROM.

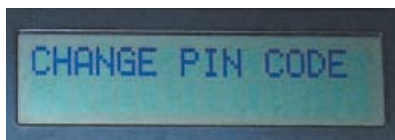
Having set the contrast, put the program into "Engineer's Mode" by holding down keypad D (bottom right), then pressing and releasing Reset switch S4 (mounted separately on the p.c.b.), and then releasing key D. This action allows an "authorised engineer" (i.e. *you!*) to change the main PIN code without previously knowing the correct one. On other occasions, it also resets the alarm if it has been activated, turning off the bell, etc.

Additionally, it resets various default factors:

Zones to be monitored	1 and 8
Entry/exit zone	1
Entry/exit time	30 seconds
Bell-on time	15 minutes
Keypad 2 entry time-out	30 seconds

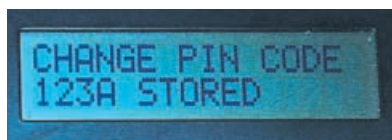
Normally, the PIN code and other factors can be amended from within the running system, but only after the correct PIN has been keyed in.

On entry to Engineer's mode, you will be greeted by the 1-line message:



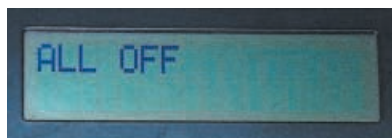
Enter your chosen 4-character PIN code using any of keys 0 to 9 and A to C, for example: 123A. The other three keys (blank, decimal point and D cannot be used for the PIN code. Each keypress is accompanied by a beep of the buzzer and its associated l.e.d. being briefly turned on.

Each accepted keypress digit will be shown on line 2. If you make a mistake, press the blank key to clear line 2, allowing you to start again. Pressing "blank" when no digits are shown exits this mode.



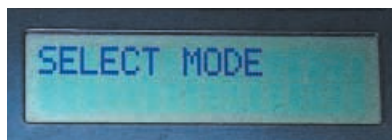
When all four digits have been entered, press D. The word STORED will now appear briefly, telling you that the code has been stored in the PIC's data EEPROM for future recall. All data EEPROM values are retained even after power has been disconnected.

The screen then displays ALL OFF on line 1, with line 2 clear. From here on, access to all modes must be prefixed by your PIN code being keyed in.



Key it in now. If you enter a wrong digit, nothing will happen. There is no screen confirmation of which key is pressed, for obvious security reasons.

When the correct PIN has been entered, line 1 displays the message SELECT MODE.



You now have a choice of eleven modes, selected by pressing one of the following keys:

- 0 Activate alarm and start exit-delay count-down
- 1 Change main PIN code
- 2 Change entry/exit time (time-out)
- 3 Set zone to be regarded as the sole main entry/exit point
- 4 Set zones required to be monitored when the alarm is active
- 5 Set bell-on time, between 1 and 20 minutes
- 6 Automatically assess zones for sensor status (normally-open or normally-closed)
- 7 Display normal zone logic (sensors n.o. or n.c.) – for information only
- 8 Select second PIN code, as required for second (optional) keypad
- 9 Set entry time for zone covered by second keypad
- (decimal point) Set "passive" mode in which any zone entry is displayed and a buzzer sounded, terminated when zone entry ceases

When new data has been keyed-in, press D to store it in the data EEPROM, confirmed by STORED appearing and a return to SELECT MODE.

All modes except "Passive" (see later) may be exited by pressing the "blank" key, but any changed data is NOT stored if you do so.

Having "escaped" from a mode, or having completed any changes permitted by it and stored them by pressing D, the screen returns to displaying SELECT MODE, and another mode selection can be made.

Pressing the "blank" key when SELECT MODE is shown, fully exits the mode selection facility, followed by ALL OFF again being displayed. It is necessary to key-in your main PIN code (keypad 1) to re-enter the mode selection facility.

Next time a "data" mode is entered the data displayed is that previously keyed in and stored.

Each mode will now be discussed in detail.

MODE 0 – activate alarm system

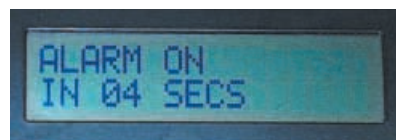
When Mode 0 is entered, the software first checks that all zones have the open or closed status as set in Mode 6 (assess zone logic). If they do not, a 2-line message is displayed, of which the following is an example:



in which zone 6 is not in the required condition (e.g. a door open when it should be closed). The allocated entry/exit zone may remain open at this time, since that is the route that will be taken by the user once the alarm has been set on.

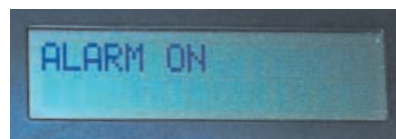
This message will continue to be displayed until the zone has been returned to its required condition, or the "blank" key pressed to exit this mode and return to a display of ALL OFF.

If the "blank" key is not used, when the incorrect zone status has been remedied, the alarm-on procedure will resume, and a 2-line message shown, such as:



where the countdown starts at the seconds value previously set for the entry/exit delay and proceeds to count down to zero. The buzzer sounds during this period.

The countdown may be terminated and a return made to ALL OFF if the "blank" key is pressed. Otherwise when zero is reached the system will be placed into the full alarm monitoring condition, "watching" those zones set through Mode 4:



An exit from and closure of the allocated entry/exit zone must be made within the allotted entry/exit time. Failure to do so will cause an alarm condition to exist.

MODE 1 – Change main PIN code

Discussed previously.

MODE 2 – Change entry/exit time

On selection of Mode 2, the screen displays a 2-line message such as:



where the value following PREV is the previously set time-out period in seconds.

Any value between 01 and 99 may be selected (note the prefix 0 for values below 10). Each digit entered is displayed at the bottom left of line 2. If you make a mistake, press the "blank" key to clear the value just entered, allowing you to start again. Note that you are returned to the SELECT MODE display if "blank" is pressed when only one digit has been entered.

If more than two digits are keyed in succession, the others will be ignored.

MODE 3 – select entry/exit zone

On entry to Mode 3, a 2-line message will be displayed, such as:



where in this instance the numeral 1 indicates that Zone 1 is currently the selected entry/exit zone. As MAX 6 states, one of six zones can be nominated as the entry/exit zone. Pressing any key between 1 and 6 selects that zone and the chosen digit appears, replacing the appropriate "dash", and with a "dash" now replacing the previous digit.

Zones 7 and 8 cannot be selected for entry/exit as these are regarded by the software as being for anti-tamper and Panic zone use.

MODE 4 – select zones to be monitored

On entry to Mode 4, a 2-line message will be displayed of which the following is an example:



This example shows that zones 1 and 8 have been selected for unauthorised access monitoring. If any of these zones are entered when zone monitoring is active, an alarm condition will exist, accompanied by the bell and buzzer sounding, and the strobe flashing (if installed).

The exception is when the zone entered is that allocated as the entry/exit zone. If this zone is entered during active monitoring, the entry/exit countdown timer will start, with the buzzer sounding. If the correct PIN code is keyed-in within the allotted time (see Mode 2) the system will be deactivated and the buzzer silenced. If the entry/exit delay is exceeded, then the bell and strobe will be activated.

When in Mode 4, pressing any key between 1 and 7 will toggle that zone between "active" (watched) and ignored. When selected, the zone number will be displayed, otherwise a "dash" will be shown). Note the following, however:

- Zone 8 cannot be deselected as the software regards this as being a "Panic" zone.
- Zone 7, nominally allocated as an anti-tamper zone, can be selected/deselected.
- Any zone nominated as the entry/exit zone cannot be deselected.

- When in Mode 2 (set entry/exit zone) the selected zone automatically causes the same "Watch" zone to be activated.

MODE 5 – Set bell-on time

On entry to Mode 5, a 2-line message will be displayed of which the following is an example:



Through this mode you can set the time for which the bell is turned on if unauthorised entry to a zone occurs. There is a legal limit in the UK of 20 minutes maximum. You may set a time between 1 and 20 minutes.

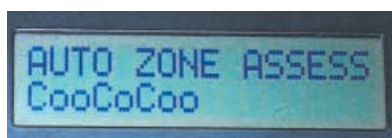
In the above example, the previously set bell-on time is shown as 12 minutes, with the MAX20 reminding that 20 minutes is the maximum. On line 2, "??" is where your newly selected time is displayed when you press the permitted numeric keys.

The first digit (the "tens" of minutes) can only have a value between 0 and 2. A value between 0 and 9 can be keyed for digit 2 (the "units"). The following conditions apply, though:

If digit 1 has a value of 2, only 0 can be entered for digit 2. If digit 1 has a value of 0, a value of 0 cannot be keyed in for digit 2. This ensures that only a time between 1 and 20 minutes can be selected.

MODE 6 – Auto zone assess

On entry to Mode 6, a 2-line message will be displayed of which the following is an example:



This mode allows the system to assess whether it should be monitoring individual zones as normally-open or normally-closed. The letter "C" in any of the eight positions on line 2 indicates that a zone sensor is currently closed, letter "o" shows that it is currently open.

In this example, zones 1, 4 and 6 are shown as having normally-closed logic. Zones 2, 3, 5, 7 and 8 have normally-open logic.

The settings shown in line 2 can be stored to the data EEPROM by pressing D, they will then be the settings that the system checks are correct when in active monitoring mode. Should any sensor be found to be in a different condition, and that zone is one of those selected to be monitored (see Mode 4), then an alarm condition exists. The system then behaves as described under Mode 4 (bells etc.).

Before pressing D to store the data, physically visit all zones and ensure that the sensors are in the required condition, i.e. doors and windows closed, the cat not sitting on the pressure mat, wife not moving around in front of the PIR sensor, etc.

Except for "blank", all other keys are ignored in this mode.

MODE 7 – View normal zone logic

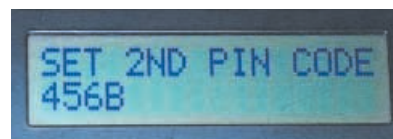
On entry to Mode 7, a 2-line message will be displayed of which the following is an example:



This mode is for information only. It simply shows the normally-open and normally-closed logic for each sensor as stored in the data EEPROM – in this case they are all shown as normally-open.

MODE 8 – Set second keypad PIN

On entry to Mode 8, the following line 1 message will be displayed (but with line 2 blank):

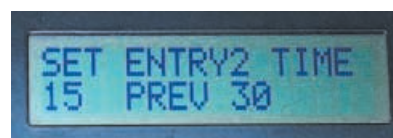


Mode 8 is used in the same way as Mode 1, but allowing you to enter the required 4-digit PIN for use with the optional keypad 2. It may be the same PIN as used with keypad 1, but it does not provide access to the main system.

Note that if you have chosen to use just a 4-wire connection to keypad 2 (as discussed earlier) you can only use those keys for which wiring exists. All others will be ignored.

MODE 9 – Set keypad 2 entry time

On entry to Mode 9, a 2-line message will be displayed of which the following is an example (after the new entry time, 15 secs, has been keyed-in):



This mode sets the time during which the auxiliary output (transistor TR4) and the buzzer are activated when the correct PIN code has been keyed-in via keypad 2. At the end of the time-out, TR4 and the buzzer are turned off.

This mode is used identically to Mode 2.

MODE "●" – Activate "passive" monitor mode

An eleventh mode is available, entered by pressing the "●" (decimal point) key. On entry to this mode, a 2-line message will be displayed of which the following is an example:



When in this mode, all zones are monitored and if any are found to have their

sensors in the opposite logic to that expected (e.g. open instead of closed), the buzzer sounds until all sensors return to their normal expected status. The appropriate zone numbers are displayed on line 2, with the number being replaced by a "dash" when no longer triggered. In the example, zone 6 has been entered.

This facility can be used, for example, in a shop when it is desirable to know if a customer has opened a door, or removed an object from where it should be.

"Passive" monitoring is terminated by keying in the PIN code, to return to SELECT MODE.

MODE SUMMARY

The following is the summary of the modes and their keyed identities. It is suggested that you photocopy it and secure the details to the front panel of your enclosed alarm.

0. Set alarm on
1. Set main PIN code
2. Set access time-out
3. Set access zone
4. Set active zones
5. Set bell time
6. Set zone logic
7. Show zone logic
8. Set 2nd PIN code
9. Set 2nd time-out
- Set passive mode

CHOICE OF SENSORS

It is believed that this design can be used with any type of intruder sensor currently available. The choice is entirely yours as to which type you use for which zone. Many companies sell intruder alarm products and they or their catalogues should be consulted for advice on the sensors available.

The choice of case and back-up battery is also yours. For the latter a sealed lead-acid type rated at 12V and, say 5Ah, is suggested. If you are using the anti-tamper option, it recommended that a microswitch is installed in the case and the bell housing, causing an alarm condition if either enclosure is entered without authority.

The system can be used to monitor just one zone. Each zone used can be connected by using 2-core cable (available specifically for alarm use). If anti-tamper detection is required, 4-core alarm cable should be used, the entry sensor itself wired to one pair, the anti-tamper connections made by the other and connected separately to the system's allotted anti-tamper terminals (zone 7).

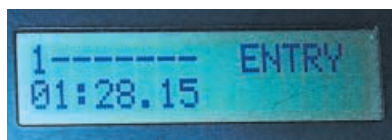
Anti-tamper wiring could be connected in series between all required zones. Alternatively the zones could be treated as separate anti-tamper connections, with each cable pair "commoned" into the zone 7 terminal block. The latter technique may make it easier to trace an open-circuit should one occur. Anti-tamper wiring should always be normally-closed.

It is debatable as to whether anti-tamper monitoring is required in a normal domestic security system.

UNAUTHORISED ENTRY

If one more zones are entered without authority, the bell, strobe and buzzer are all activated. A clock is started from zero

when the first zone is entered. The screen changes to display a message showing which zone has been triggered, plus the clock read-out, e.g.:



In this example, zone 1 is shown to have been entered and that it is 1 hour, 28 minutes and 15 seconds since that event. The clock continues counting until the alarm is reset via your PIN code. The elapsed time can reach 99:59:59 (just over four days – a long week-end, for example) and then restarts from zero.

The bell is automatically turned off after the preset delay period has elapsed, as discussed earlier. The strobe and buzzer remain on until reset by keying in your PIN code.

If a second unauthorised entry is made following the first, the bell is not reactivated, nor does this event affect the clock's current counting. It is the elapsed time since the *first* entry occurred that continues to be shown. The display, though, is updated to show the number of the second zone (or more) as well as the first.

When "Panic" mode is triggered via switch S3, the clock is always reset to zero.

If the bell time-out has not completed following zone triggering and a total power failure occurs, the bell is NOT reactivated when power is resumed, although the buzzer and strobe are re-triggered.

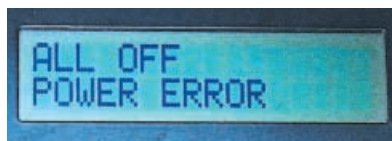
When entering the correct PIN code to stop an alarm condition and turn off the bell, strobe and buzzer as appropriate, all zone and timing information remains on screen until "blank" is pressed to cause a return to ALL OFF mode.

Be assured that even if the alarm is in active monitoring mode and use of the keypad is made, full system scanning continues, preventing unauthorised users from "fooling" the system by holding down a key indefinitely.

TOTAL POWER LOSS

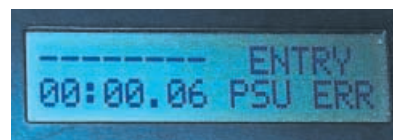
If there is a total power loss through a mains failure and lack of battery power, and then one or the other is restored, the software restarts from a Reset condition. In doing so, it notes this fact and displays one of three messages.

If the system has not been set into active monitoring mode, the following 2-line message appears:



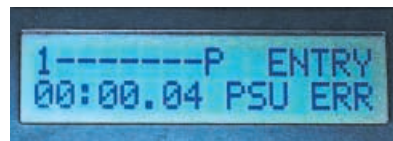
The second line is cleared when you enter your PIN code and enter SELECT MODE, from which you can immediately escape if you wish (press "blank" key).

If the alarm was previously in monitoring mode and there has been no unauthorised zone entry, a 2-line message similar to following is shown:



This indicates that no zones have been intruded and that it is 6 seconds (and counting!) since the power was restored.

If one or more zones have been intruded, the message might appear as:



indicating that zone1 has been entered and that "panic" has been pressed, again showing the elapsed time since power restoration. The message PSU ERR (or the earlier POWER ERROR) means that you should check the condition of your battery.

To clear either of the last two messages, you must reset the alarm by keying in your PIN code and pressing "blank" to return to ALL OFF.

AUTHOR'S EXIT

The PIC Monitored Intruder Alarm has not been tested "in active service". However, it has been extensively bench tested with a variety of switches and sensor-simulation devices. It is believed that it lives up to the specifications outlined earlier, but this cannot be guaranteed and no legal responsibility can be accepted for it.

However, if you have any suggestions for how the system could be improved, please advise us at Editorial HQ (not via the *Chat Zone* since we do not visit this regularly).

May you live without intrusion!

RESOURCES

Software for this design is available on 3.5-inch disk (for which a nominal handling charge applies). It is also available for free download from ftp site. (See PCB Service page.)

Read this month's *Shoptalk* page for additional details on obtaining the software, plus pre-programmed PICs, and general information on buying components for this PIC Controlled Intruder Alarm. □



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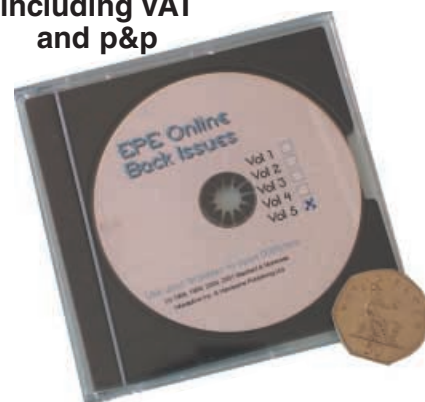
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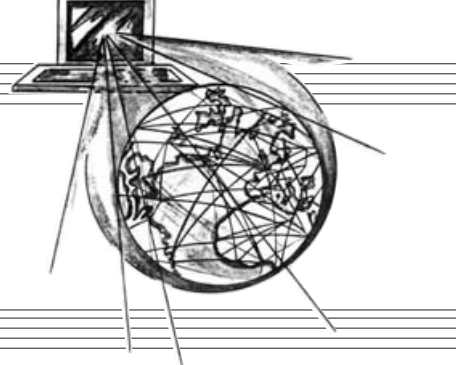
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NET WORK

ALAN WINSTANLEY



WELCOME to this month's *Net Work*, our column specially written for users of the Internet. Remember that you can buy most of *EPE*'s books, back issues, p.c.b.s, videos and CD-ROMs online via our Online shop at: www.epemag.wimborne.co.uk/shop-door.htm and you can also subscribe for 6 months, 1 or 2 years by taking out a subscription online at subrates.htm.

Of course, you can download the source code for nearly all our PIC projects by hopping over to our FTP site (<ftp://ftp.epemag.wimborne.co.uk/pub>) – links are provided on the home page of our web site, and a mirror web site of our PIC codes is maintained by Thomas Stratford at <http://homepages.nildram.co.uk/~starbug/epemag.htm>. Also on our FTP site are several other files and folders supporting Robert Penfold's *Interface* column.

A Catalog of Problems

Recently my phone rang and it was a UK sales manager for Actinic Software, who busied himself describing their latest packages, support contracts and upgrades for their e-commerce software systems. Some readers may be aware of the problems that we suddenly experienced in January 2002 when our own system – based on Actinic Catalog – failed to update itself properly and some key features were corrupted.

This disruption resulted in a lot of hair-pulling and a major outage that lasted nearly two weeks while different servers and operating systems were tested and double-checked. After a lot of hard work by both ourselves and our ISP, we're pleased to see the system fully restored and working faster than ever before.

One important change with the online system is that a Java applet is now used at the order encryption phase. The applet is based on 128-bit security to encrypt credit card information in your browser and it is much faster than waiting for a lengthy Perl script on a slow secure server to run.

One drawback is that Windows XP users may not be able to run the Java applet without first downloading the Java Virtual Machine from the Microsoft web site. The reasons why Microsoft offers you this Internet download rather than include it on the XP CD are spelt out in their Open Letter to Sun Microsystems at www.microsoft.com/java/issues/openletter.htm.

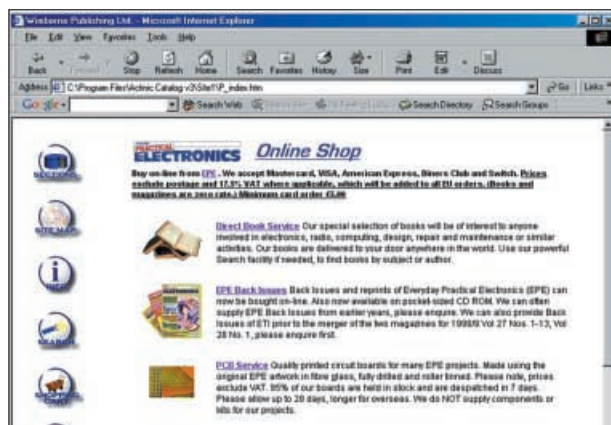
Unfortunately, those operating behind a firewall that prohibits applets from running will not be able to place an order. This is a rare occurrence but we are unable to offer any other way of accepting or processing online payments for goods bought via the online shop.

Every cloud has a silver lining though, and the faster server finally enable users to run a search quickly, so simply type any keywords such as "PIC Toolkit" into the Search box and all instances of books, p.c.b.s, CDs and back issues containing this expression will be listed. Full terms and conditions are available online under the "Info" button, and if you want a clearer way of navigating the shop, try using the Site Map function instead.

You Have (Junk) Mail

In the November 2001 issue I outlined ways in which you can take better control of your email. Spam or junk mail is getting worse all the time, and readers are reminded that posting any message into Usenet is a surefire way of getting your email address onto spammer's mailing lists, so never use a critical work email address when posting into newsgroups unless you relish the taste of spam.

Various come-on tactics are used to try to get you to read incoming junk mail. The subject line is the first thing you see, so it may say "Hi! Here's the info you asked for! 38954" – the randomised number is there to beat any spam filters. It is easy enough to filter out anything containing, say, a \$ sign or the word "mortgage" but no matter how much you relish the challenge of configuring your mail's filtering rules, unwanted mail is sometimes best dealt with by deleting it manually from the mailserver.



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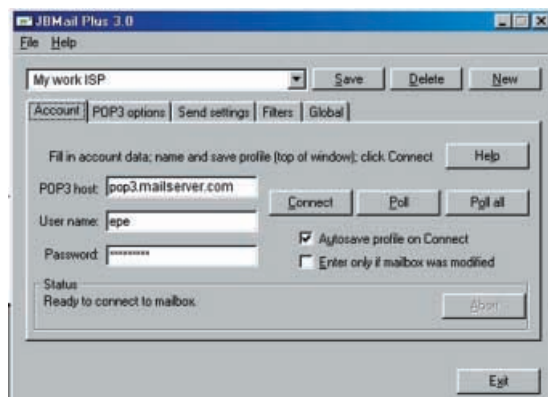
However, many users are not aware that it is possible to access mail on the server without needing to download it into your own mail client (e.g. Outlook Express or Eudora) first. Nor do you need to ask your ISP's technical support – you can handle this easily for yourself.

One package I suggest is JMail which will poll multiple mailboxes automatically so that you can manually screen out unwanted mail. This morning one of my mailboxes contained nearly 50 junk emails that arrived overnight from the USA, but they were all deleted satisfyingly at a stroke using JMail. Another mailbox started to fill before my very eyes with junk just after I had cleaned it out! The downside is that it is easy to overlook legitimate mails needing your attention, so care is needed when sifting through the debris.

A new Version 3 of JB Mail has now been launched which includes the very significant upgrade of multiple address books (e.g. work, friends). This data can be imported as a tab-delimited file, and you can also create your own address books as well. New blacklist filters are included, and one of JMail's most valuable features is its ability to poll multiple mailboxes at once.

Remember that you're dealing directly with the mailserver, so if you want to keep any correspondence you must save it out as a file. Any mail deleted from the server is gone for ever if you "save" that session when exiting the software. It can be ideal for firing off quick replies in real time rather than using your regular offline mail client.

You can contact the writer at alan@epemag.co.uk.



JMail Version 3 now has a built-in address book and other improvements.

MANUAL STEPPER MOTOR CONTROLLER

THOMAS SCARBOROUGH

Keep in step with this novel low-cost controller.

A HIGH SCHOOL student recently contacted the author for help in building a robotic arm for a school project. He had some stepper motors on hand, and was looking for a simple way to utilise them.

Unfortunately there didn't seem to be any really simple way to do it – nor could the author find any published design to help – at least not any that fitted the description of “simplicity itself”.

A typical stepper motor control system incorporates a microprocessor control unit, a drive card, and a dedicated power supply unit – as well as, of course, the motor itself.

The author perceived in this a basic problem. The barrier between owning a stepper motor and actually using it is fairly great. Contrast this with the easy availability of stepper motors today, particularly from cast-off 5¼in. disk drives and fax machines, and you clearly have a problem waiting for a solution.

HOW IT WORKS

The present article describes a simple way to rotate a four-phase unipolar stepper motor with the help of a single rotary switch, just eight inexpensive rectifier diodes, and some incidental components. The full circuit diagram for the Manual Stepper Motor Controller is shown in Fig.1.

Turn the rotary switch S1 clockwise, and the stepper motor turns clockwise. Turn the rotary switch anticlockwise, and the stepper motor turns anticlockwise. Bring the rotary switch to rest, and the stepper motor comes to rest at full torque (called holding torque).

This mimics the basic control features available from standard stepper motor controller i.c.s – with the exception that the Manual Stepper Motor Controller is operated entirely by hand.

It also incorporates basic feedback in the form of light emitting diode (l.e.d.) D10 and magnetic reed switch S2, so that if the

motor is mounted out of sight, the user may know when it has completed one full rotation.

Possible applications include the remote positioning of lights or vents, the manual rotation of the hands of a wall-mounted clock, or the remote control of robots and robotic toys.

CIRCUIT THEORY

A four-phase unipolar stepper motor may typically be controlled in four different ways – all of which have advantages and disadvantages:

- **Wave control** – This is the simplest form of control, as it energises only one winding (or phase) at a time. Its main drawback is poor torque.
- **Full-step control** – This is a simple means of control with good torque, utilising two windings of the motor at a time.
- **Half-step control** – This is a more complex form of control, combining wave control with full-step control (it therefore has twice as many steps). It has good torque, and stabilises motor operation. However, it is not suitable for our purposes here, above all for its loss of torque under manual control.



- **Micro-stepping control** – This is a complex form of control, with sophisticated circuitry, which enables countless “in between-in between” steps, and great precision. It is frequently used in industry.

The method of control which best suits our purposes here is *full-step control*, since it is both easy to implement and has good torque. This requires a 4-bit binary control sequence to be shifted right or left across a stepper motor's leads.

A single-pole four-way rotary switch would accomplish this task with the help of eight multiplexing diodes. However, since such switches generally do not have 360 degrees rotation, a three-pole four-way rotary switch is used instead.

A standard break-before-make rotary switch is not really suitable here, since it would cause power to be lost momentarily across the leads of the motor during rotation, and this would adversely affect torque, especially if the motor is vertically mounted. Therefore, a *make-before-break* rotary switch is used. This *makes* a new contact *before* it breaks the previous one. Electrolytic capacitor C1 picks up the momentary surge in power when the switch “makes”.

If no holding torque is required, the circuit may be switched off once the stepper motor has been turned to its desired position. Detent torque (the remaining torque

when the stepper motor is switched off) is typically one tenth of holding torque. Red l.e.d. D9 indicates the state of On/Off switch S3.

MOTOR LEAD IDENTIFICATION

In reality there appears to be no standard colour-coding for identifying the leads of a four-phase unipolar stepper motor. The author tested six four-phase unipolar stepper motors, of which only two had the same colour-coding for the leads (every wire was brown)!

Such motors sometimes have five leads, sometimes six – sometimes even eight leads (there being four windings, or phases, in all). Fortunately, the task of lead identification is not too difficult. Current only flows in one direction in the windings (hence the designation “unipolar”), and this considerably simplifies identification.

The first step is to find the common lead or leads. A six-lead four-phase unipolar motor has two common leads, and these are most likely to be in the centre of two rows of three. It is frequently used in printers or fax machines.

A five-lead motor has a single common lead. This kind of motor is commonly used in 5¼in. disk drives. We shall omit eight-lead motors from our discussion here, since these are far less common, and their leads more difficult to identify.

COMMON LEAD

It is easy to test with a multimeter which is the common lead:

If there are six leads, measure the resistances across every possible combination of leads (e.g. green-white, green-red, white-red . . .), but ignore any measurements that indicate open circuit (an infinitely great resistance). Which leads were always involved where the lowest resistances were measured? These are the common leads. Twist or solder these two leads together into one.

Table 1: Wave Control

Step	A	B	C	D
1	ON	OFF	OFF	OFF
2	OFF	ON	OFF	OFF
3	OFF	OFF	ON	OFF
4	OFF	OFF	OFF	ON

In the case of five leads, just one lead will be found to be consistently involved where the lowest resistances are measured. This is the common lead.

IN CONTROL

Most four-phase unipolar stepper motors use a 12V power supply, or thereabouts – small variations matter little for our purposes here. A regulated 12V supply is recommended, since an unregulated supply may rise substantially above 12V, and cause the motor to heat unnecessarily or even burn out. The power supply should provide 6W or 500mA for smaller motors (3cm to 4cm dia.).

The next step is to wire up the motor's common lead to the positive terminal of a 12V regulated supply.

Now take the negative (0V) lead of the 12V supply, and apply it to the motor's four spare leads in various sequences. Once you have found a sequence that advances the motor in small steps in a clockwise direction, label these leads A to D. What you have just achieved is wave control, see Table 1.

Finally, the windings A to D need to be energised in the sequence shown in Table 2, which is full-step control. A pictorial representation of the windings (or phases) A to D is shown in Fig.2.

Data sheets may present Table 2 in different ways, and at first sight such tables might seem incompatible with each other. The table drawn here is the most logically coherent way, so that you will be able to appreciate the shifting of the binary sequence 1-0-0-1 across the stepper motor's leads.

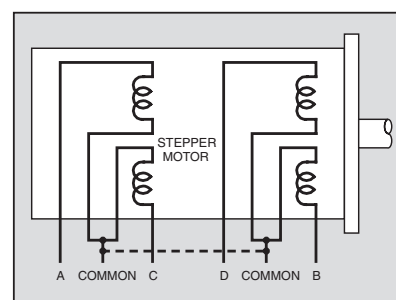


Fig.2. Unipolar drive.

Table 2: Full-step Control

Step	A	B	C	D
1	ON	OFF	OFF	ON
2	ON	ON	OFF	OFF
3	OFF	ON	ON	OFF
4	OFF	OFF	ON	ON

CONSTRUCTION

The specified rotary switch S1 has an external adjustable rotation limit stop metal washer which prevents full rotation. We need full rotation for this project – so the metal washer is discarded.

Certain types of rotary switches may need further “butchering” and this means you must carefully prise open the switch, observing where each part fits. At the bottom of its black well, at the side, is an internal rotation limit stop (a small plastic notch, which is integral to the plastic

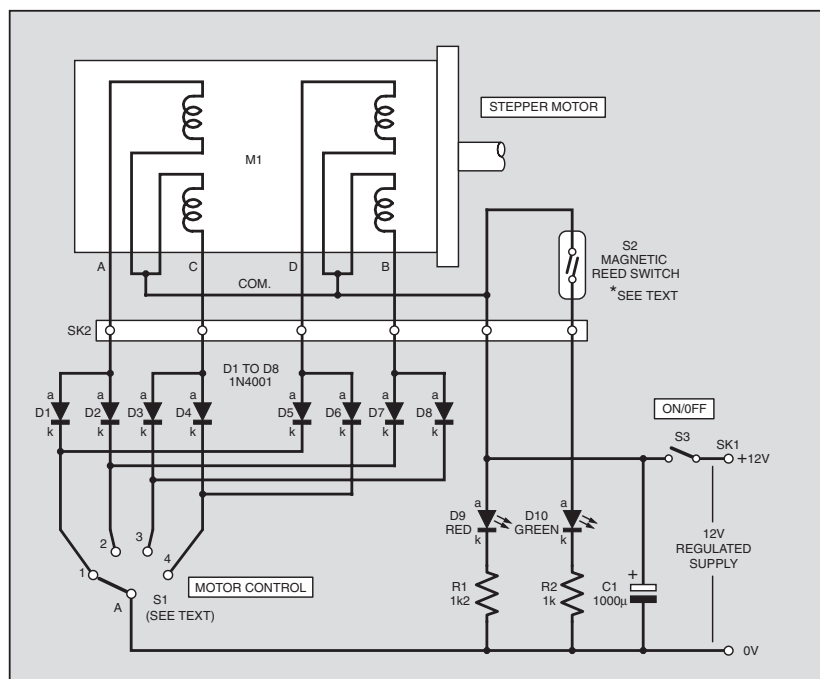


Fig.1. Complete circuit diagram for the Manual Stepper Motor Controller. Switch S1 must be a make-before-break type.

COMPONENTS

Resistors

R1 1k2
R2 1k
All 0.25W 5% carbon film

See
SHOP
TALK
page

Capacitors

C1 1000µ radial elect. 16V

Semiconductors

D1 to D8 1N4001 50V 1A rect. diode (8 off)
D9 5mm red l.e.d.
D10 5mm green l.e.d.

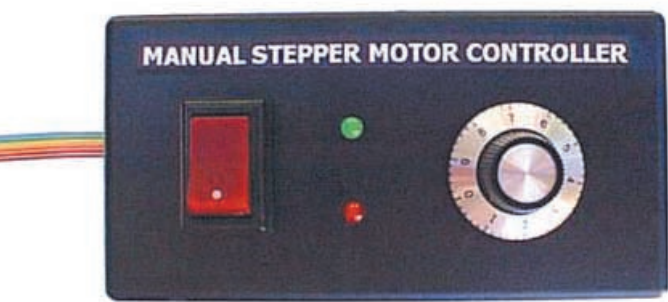
Miscellaneous

M1 12V d.c. four-phase unipolar stepper motor
S1 3-pole 4-way make-before-break rotary switch (see text)
S2 small reed switch, with magnet (or flush mount alarm switch combination)
S3 s.p.s.t. rocker switch
SK1 2.1mm power socket, single hole fixing
SK2/SK3 6-way straight p.c.b. header, with crimp terminal plug (2 off)

Stripboard, 0.1in. matrix size 24 holes by 16 strips; 6-way multicoloured ribbon cable; plastic case, size to choice; 15cm length of flexible wire (3 off); knob with fixing nut; solder, etc.

Approx. Cost
Guidance Only
excluding case & stepper motor

£10

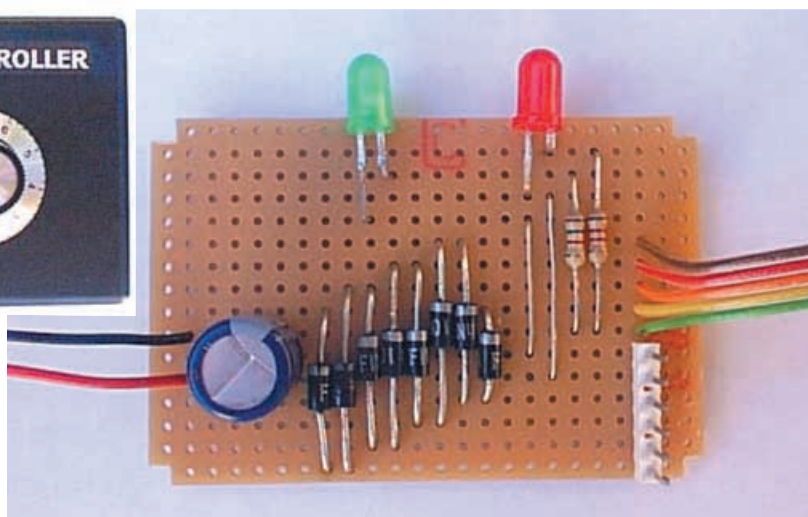


moulding). Cut this out, then test to see that there is smooth 360° rotation of the switch before carefully snapping it back together again.

This simple Manual Stepper Motor Controller project is built on a single piece of 0.1in matrix stripboard, measuring 24 holes by 16 strips. The topside component layout and interwiring is shown in Fig.3. There are no breaks in the underside copper tracks. A length of 6-way multi-coloured ribbon cable, attached at each end with "female" pin-header plugs, is used to interlink the circuit board to the stepper motor.

Commence construction by soldering in position the two link wires, the p.c.b. header SK2 (the leads to the stepper motor are plugged on here), and the two resistors, continuing with the eight diodes, the two l.e.d.s, and the capacitor. The cathodes (k) of diodes D1 to D8 are banded. The cathodes of l.e.d.s D9 and D10 have the shortest leads, and have a flat on the body nearest these leads.

Be sure also to observe the correct polarity of capacitor C1. L.E.D.s D9 and D10 are mounted on the stripboard in such a



Components mounted on the completed circuit board.

way that they will protrude through the front panel of the case when the board is slotted into place.

WIRING UP

Prepare three lengths of flexible wire, each about 15cm long. Strip the ends, and tin them with solder. These leads are taken from the board to power socket SK1 and on-off switch S3 as shown in Fig.3. Prepare a 15cm length of 5-way ribbon cable, stripping the ends and tinning them with solder. This is also taken from the stripboard to rotary switch S1 as shown.

Finally, prepare a length of 6-way ribbon cable of any desired length, inserting the six ends into a six-way female crimp terminal,

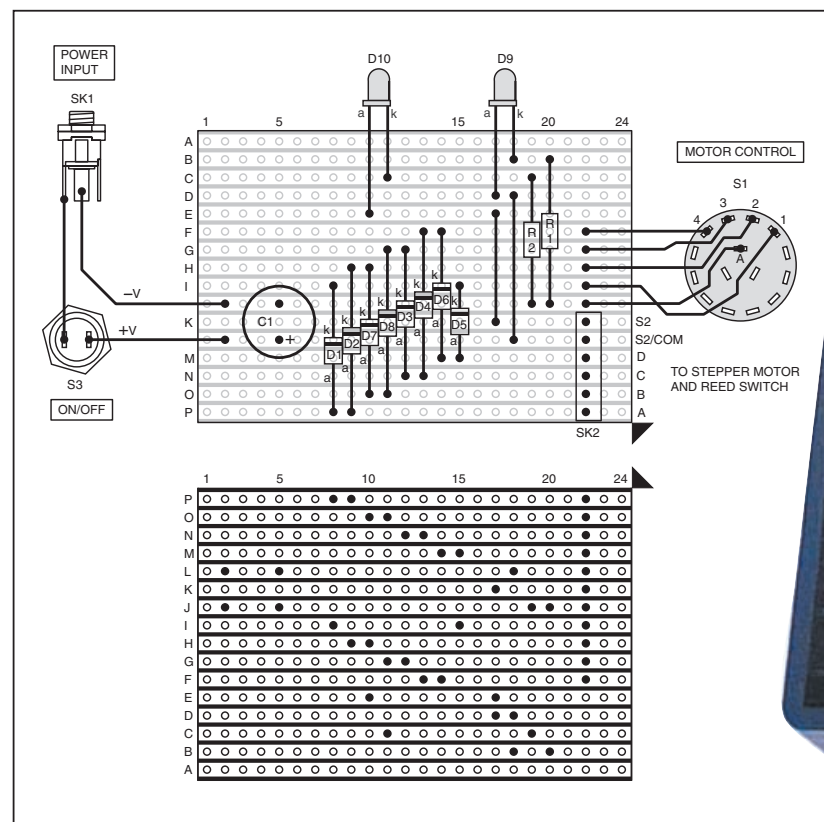
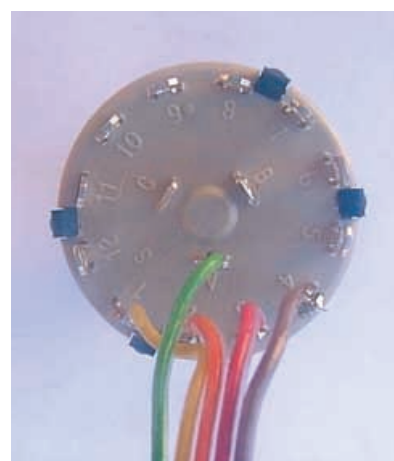
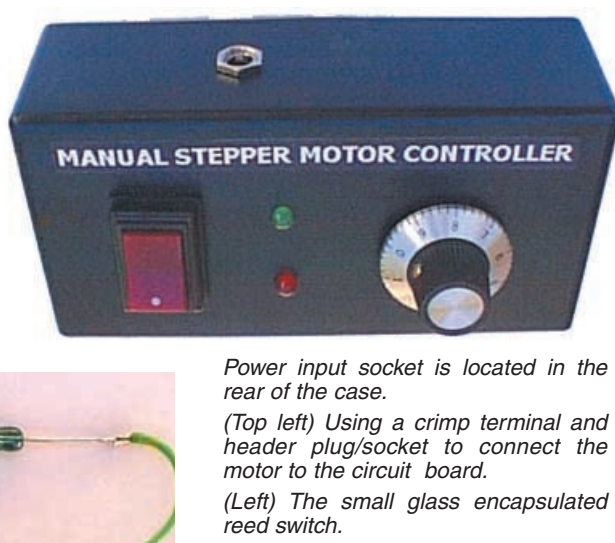
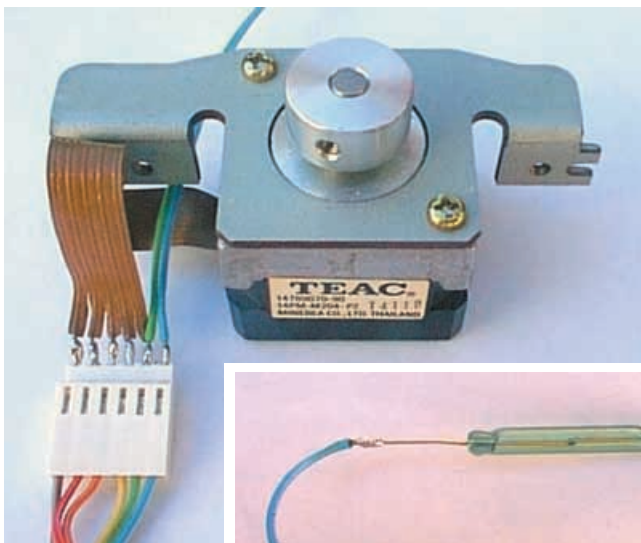


Fig.3. Stripboard component layout and interwiring for the Manual Stepper Motor Controller. Rotary switch S1 **MUST** be a make-before-break type.





Power input socket is located in the rear of the case.

(Top left) Using a crimp terminal and header plug/socket to connect the motor to the circuit board.

(Left) The small glass encapsulated reed switch.

header plug which then plugs onto the p.c.b. type header SK2. The ribbon cable is taken to the stepper motor, and the author again used a crimp terminal at the far end of the ribbon cable to attach it to the motor, soldering the motor's leads directly to a p.c.b. header. In this way, cables and motors can be fairly easily swapped in and out.

A magnet is mounted on the motor's shaft (or on whatever mechanism may be attached to the shaft) in such a way that it will close reed switch S2 as the magnet passes by.

If a more powerful stepper motor is to be used, you may increase the rating of the rotary switch S1 by wiring every solder tag of the switch's three poles in parallel, and

increasing the value of capacitor C1. In this way, the switch can manage currents of almost 0.5A.

Finally, the control circuitry may be fitted into a suitable case. The specified case allows the stripboard to be slotted into place so that l.e.d.s D9 and D10 protrude through the front panel – see photographs.

IN USE

All that remains is to apply power (12V 500mA), and turn the rotary Motor Control switch. All being well, the stepper motor will turn with it.

Do not reverse the power supply polarity. Whilst reverse voltages hold little

danger for the stepper motor, which would simply refuse to turn, it could severely damage capacitor C1.

Although most 12V unipolar stepper motors are rated 12V continuous, they may generate an uncomfortable amount of heat. If full torque is not required, a simple solution is to insert a 15 ohm 10W or other suitable resistor in one of the supply lines.

The pull of a small four-phase unipolar stepper motor is fairly strong between the fingers, and such motors could find many uses – all for an outlay which is many times less than that of a typical stepper motor control system.

Thanks to high school student Stuart Shapiro for asking the question. □

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PHILIPS PM3238 sig gen, 100kHz-160MHz with
200MHz, freq. counter, IEEE ... £550
RACAL 9081 Synth AM/FM sig g en, 5kHz-1024MHz ... £250
H.P. 3325A Synth function gen, 21MHz ... £600
MARCONI 5500 Amplitude Analyser ... £1500
H.P. 4192A Impedance Analyser ... £5000
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H.P. 8903A Inductance Analyser ... £1000
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H.P. 66309D PSU, 0-15, 0-3A/0-12, 0-1-5A ... £750
H.P. 6632B PSU, 0-20V/0-5A ... £500
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H.P./AGILENT 34401A DMM 6 1/2 digit ... £400/£450
H.P. 3478A DMM 5 1/2 digit ... £275
FLUKE 45 DMM dual display ... £400
KETHLEY 2010 DMM 7 1/2 digit ... £950
KETHLEY 617 Programmable Electrometer ... £1250
H.P. 4338B Milliohmometer ... £1500
RACAL Counter type 1999 2.6GHz ... £500
H.P. Counter type 53131A 3GHz ... £850
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H.P. 8657B Syn Sig. Gen, 0-1-2080MHz ... £2500
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H.P. 8560A 50Hz-2.9GHz synthesised ... £5000
H.P. 8594E 9kHz-2.9GHz ... £4500/£5000
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ELECTRONIC PRINCIPLES V7.1 REVIEW

ROBERT PENFOLD

Robert tries the Soft approach to electronics and computing and finds it well thought out and easy to use.

THE Electronic Principles software package has undergone a few changes since Version 5 was reviewed in a 1998 issue of *EPE*. At Version 7 it was actually split into two separate programs, called Electronic and Computing Principles, and Computer Science and Mathematics Principles. However, it was merged back into one program at Version 7.1, and it is currently sold as Electronic and Computing Principles.

The program is not fundamentally different from Version 5, or even earlier variants, and it is a collection of screens that provide tutorials on various aspects of computing, electronics, mathematics, basic physics, etc. The main difference from one version to the next is the range of topics covered and the number of screens in each section. The range covered by V7.1 is vast, but it remains reasonably easy to navigate your way to the desired topics.

Getting Started

The program is supplied on a single CD-ROM and it is installed via the usual Setup program. Provided you have a suitable PC this

should proceed reasonably quickly and reliably. The minimum requirements to run this program are not very demanding, and practically any PC running Windows 95 or later is suitable. This is useful for educational establishments where the computers are something less than "state of the art".

The program is fully installed onto the computer's hard disk. This avoids the need to have the CD-ROM in the drive when the program is in use, and ensures that everything runs smoothly and quickly. About 45 megabytes of hard disk space is required, which makes the program quite compact by current standards.

... You will not spend hours learning to use this program before you can actually start learning from it.

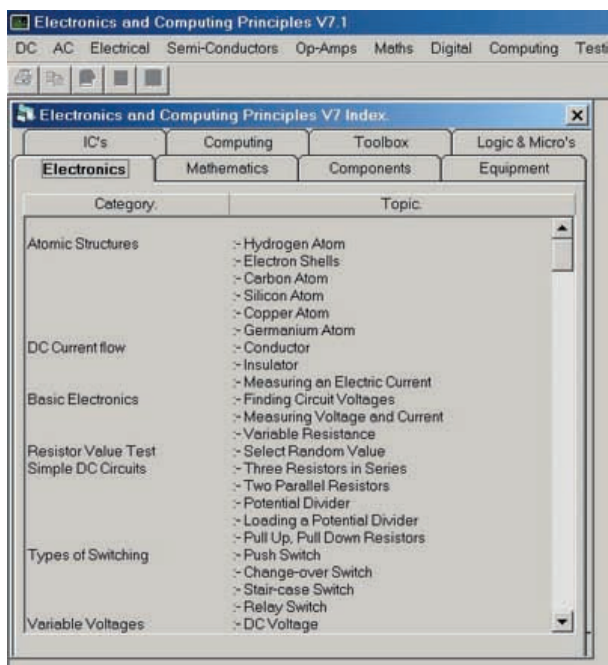


Fig.1. The opening screen. The program is less conventional than it first appears.



Keeping Tabs

A screen like the one shown in Fig.1 appears when the program is first run, and it offers two ways of selecting the required pages.

At the top of the screen there is the usual Windows style menu bar, but this does not have the usual headings such as File and Tools. Instead, it provides menus for Op.Amps, Digital, Computing, etc.

For example, Fig.2 shows the A.C. menu, which offers subjects such as inductance, a.c. theory, and active filters. Selecting a menu option brings up the appropriate window for that topic. However, in most cases it is only the first page for that topic that appears. Others are available from the pop-down menu at the bottom of the screen as shown in Fig.3.

There are so many pages available that a second method of accessing them has been included. An Index window opens

Fig.2. Many of the pages can be accessed via the menu system.

automatically when the program is launched (see Fig.1), and this provides an easy way to search for the exact topic that you require.

The eight tabs at the top of the window are used to select the general area of interest, such as electronics or components. A scrollable list of all the relevant pages then appears. In order to launch the required page it is merely necessary to double-click on its entry in the Index window.

Using the menu system provides the quickest means of accessing pages, but with so many pages available the Index window is the more practical means of navigating the program. In addition, some of the pages can only be accessed via the Index window. Some of the lists in the index are very long, but the use of sub-headings makes it easier to find the required topic. Considering the huge range of topics and pages on offer, finding your way around the program is remarkably easy.

Interactivity

Some of the pages are in HTML and consist of a colour photograph plus some text. For example, all those in the Components and Equipment sections fall into this category. The general idea is to provide familiarity with real world equipment and components, which should make life easier for those who progress to designing and building real circuits. A good range is covered in both categories. In the components section for instance, there is everything from fuses and battery holders to I.e.d.s and displays. Part of the page covering I.e.d.s (light-emitting diodes) is shown in Fig.4.

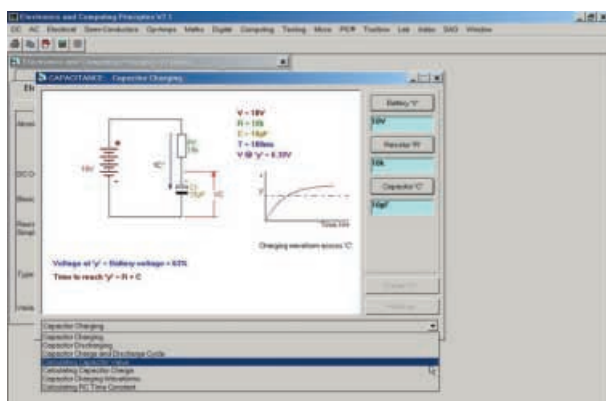


Fig.3. Further pages on the same basic topic can be accessed via a pop-down menu.

Most of the pages consist of a diagram or diagrams plus some explanatory notes. Where appropriate, formulae and calculations are also included. The vast majority of these pages are interactive in some way, and this makes the learning process easier and more fun.

As a simple example, Fig.5 shows the window for an active low-pass filter. The input voltage and the values of important components can be changed by operating the appropriate button. The dialogue box that appears when the button for resistor R2 in the filter circuit is pressed is shown in Fig.5.

The new value is typed into the textbox and then the OK button is operated. The figures in the circuit then change to suit the new value, as do the calculated cut-off frequency, output

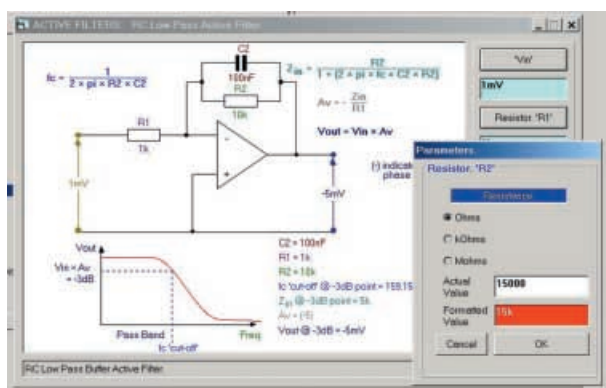


Fig.5. Most of the pages are interactive and permit some form of user input.

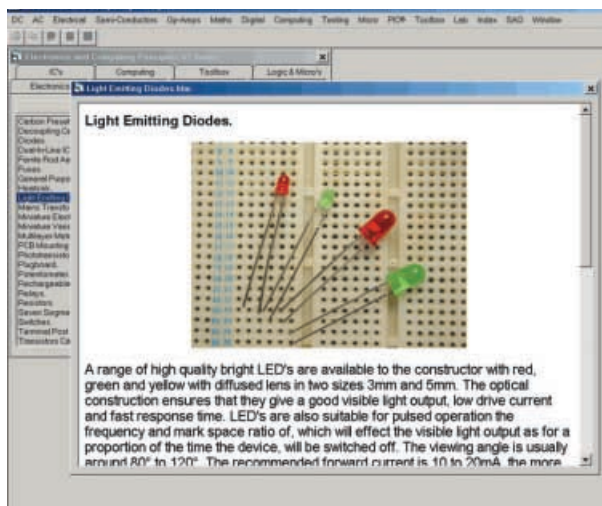


Fig.4. One of the HTML pages, this one covers I.e.d.s (light-emitting diodes).

voltage, etc. (see Fig.6). Most interactive pages use the same method of altering parameters and displaying the changes that are produced.

... The range covered by Version 7.1 is vast, but it remains reasonable easy to navigate your way to the desired topics.

In Control

Although most pages rely on buttons and dialogue boxes for user input, the method of control is altered slightly to suit certain types of circuit. In particular, the method of control is slightly different for most logic circuits. With the D-type flip/flop for example, two buttons enable the logic states of the Data and Clock inputs to be toggled. The onscreen logic indicators change in response to these input signals.

In other pages there are slider controls to provide variable voltages, analogue voltmeters and graphs to show voltage changes, and so on. There is good use of graphics, and even some simple animations such as the one that shows how a raster image is produced (see Fig.7). Overall the user interface is very consistent, and it is usually pretty obvious in operation.

Coverage

The range of topics covered goes well beyond basic electronics, and there are plenty of pages covering mathematics, and computing. The Logic and Micro's section includes some coverage of the PIC microcontrollers. Examples are based on the PIC16F84 and PIC16C71 chips. These chips are not the most up to date in the range, but nevertheless remain a good starting point.

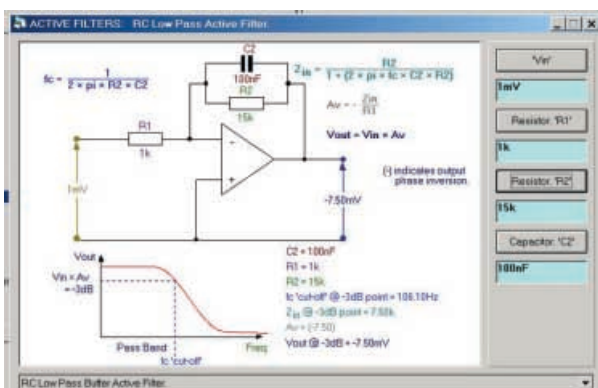


Fig.6. The calculated figures have changed to suit the change in the value of resistor R2.

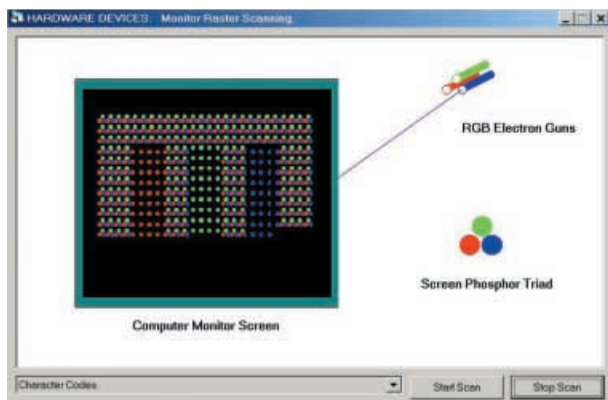


Fig.7. Some of the pages use simple animations, as in this example that shows how a raster image is built up.

It is not possible to simulate programs, but the relevant registers can be loaded with values and then an instruction can be run. The page for the DECF f,d instruction is shown in Fig.8. The values in the registers show the changes produced by running the instruction, so that the student can see the exact effect of each instruction. In addition to the pages covering the instruction set, others cover topics such as the clock oscillator, PIC architecture, and the Status register.

Tools For The Job

The small toolbar just below the menu bar provides some useful functions. Starting with the button on the extreme left, this is

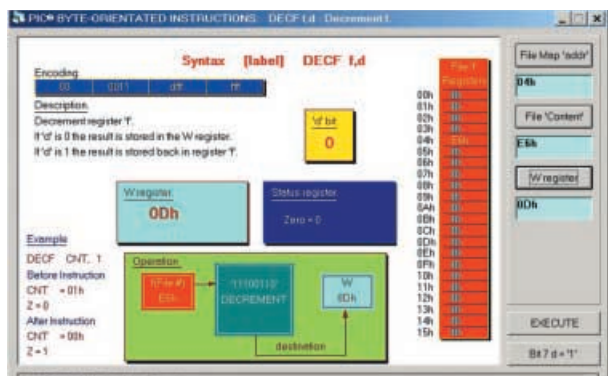


Fig.8. PIC instructions can be tried by loading values into the registers, executing the instruction, and noting the changes.

operated in order to print the current page on the default printer. The relevant topic notes are also printed, and these are explanatory notes that can be brought up for any page by operating the third button in the toolbar. The notes appear in a second window that can be removed by left clicking on a passive part of the screen.

Operating the second button in the toolbar copies the current page to the Windows clipboard. From here it can be pasted into other programs such as a DTP type, so that it can be formatted prior to printing.

Where appropriate, the fourth button can be used to show any calculations in a separate window. The calculations will reflect any changes made by the student. The fifth button has a similar function, but displays any graph in a separate window. Again, if the student makes any changes to the default values, the contents of the window will change accordingly. Obviously, the calculations and graphs are not applicable to all pages, but where available they are included on printouts.

Conclusion

It is not possible to give details of the full range of topics covered by Electronic and Computing Principles V7.1, because it is too vast. There are over a thousand pages available in the current version. Full details are available from EPTsoft and at their web site. It is relevant to a number of examination courses that cover basic electronics and (or) computing.

The program is well thought out and seems to be completely stable in use. Electronic and Computing Principles remains easy to use despite the huge number of pages available in version V7.1. You will not spend hours learning to use this program before you can actually start learning from it.

It has to be pointed out that it is not an electronics course, but a number of pages devoted to electronics and related topics. When used in educational establishments there will be a tutor to guide students through the material. It would presumably be possible to learn a great deal by going through the pages in each topic. However, for those studying at home it would probably be better to use the program in conjunction with a suitable course book.

By the standards of educational software, *Electronics and Computing Principles V7.1* is very reasonably priced at £119.99, inclusive of VAT. A multi-user network version is also available. The software is also available from Maplin Electronics and readers can now play with a copy in their stores (product code RR63).

There is a *Free trial* "Electronics and Computing Principles OnLine" demonstration version available from the EPTsoft web site. Students and hobbyists can extend this to 12 months' unlimited use by taking out a subscription for the sum of £29.95 plus VAT.

For more details contact EPTsoft Ltd., Dept. EPE, Pump House, Lockram Lane, Witham, Essex, CM8 2BJ, UK. Tel. +44 (0)1376 514008, Fax +44 (0)8700 509660.

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READOUT

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John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

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★ LETTER OF THE MONTH ★

LIFE IN THE ELECTRONIC WORLD

Dear EPE,

In the October '01 issue you asked for any positive observations on employment in British Industry. My experience is now out of date, but I've no complaints. I checked and found that my first electronics book, *Basic Radio*, was given to me as a school prize in 1945. I trained as a chemist and found employment in the 1950s, when there was no problem about finding a job, in an Industrial Research Association. I kept up my interest in electronics by reading the magazines, such as *Radio Constructor* and *Practical Wireless*.

We were expected to be minor geniuses, supposedly being able to find the answer to any problem our industry threw at us. My electronics came in useful from time to time, and as the years passed I read things like *Practical Electronics*.

After a variety of related jobs, I returned to the Research Association to work on a discrete germanium transistor logic process controller, because I was capable of understanding both the electronics and the process we were trying to control. There had been a complete breakdown of communication between the non-chemical electronic equipment supplier and the non-electronic chemical users.

The crunch came some years later when changes in funding and industry reorganisation caused the transfer of the job to over a hundred miles away. There was no other organisation in the country where my particular specialised experience fitted, so I decided to try applied electronics. By now I was over 40, and even then we were supposed to be over the hill and unemployable.

Working for an instrumentation company, I quickly found I was fully at home in the environment, and when I saw a development job in the film industry I applied, and got the job of development engineer. I was designing and

building specialised interfaces for Data General Nova and Eclipse computers, using TTL logic. The small team that I was the electronics part of received a Technical Oscar from the American Motion Picture Academy and an award from the British Kinematograph Sound and Television Society.

Unfortunately I developed an allergy to film processing chemicals and had to get out. After several other jobs, I became a freelance programmer and started work on a project, assembly level programming a microcontroller, rather similar to a present day PIC.

Suffering from ill-health, I retired at 56 and took up woodturning and largely forgot about electronics, but kept on some computing. Following a triple bypass operation, I made the minor mistake of trying to go back to woodturning too soon. I should just have waited a few more weeks, but I bought a copy of *EPE* instead, and I've never got back to woodturning.

Maybe I was lucky, but I got four electronics jobs when it was supposed to be almost impossible because of my age. The industry really did quite well for me.

As well as my interest in electronics I'm researching that first piece of engineering technology to ever enter the home, the spinning wheel. I certainly have no intention of giving up learning.

Alan S. Raistrick, Oxfordshire

Thanks Alan, that's great to hear of how electronics has served you so well over the years, sorry there was not enough space for your full letter. You might be interested to know I started out in the film industry too, at Elstree/Borehamwood, as a trainee film editor. Hobbyist electronics eventually led me into full-time electronics and I too have no regrets. It's a great technology to be involved in, in whatever capacity.

Should I team up with you in doing a PIC-controlled spinning wheel?!

32-BIT OUTPUT

Dear EPE,

Just want to say "great magazine" – the *Toolkit Mk3/TK3* project is so exciting I just had to sign up for an Online subscription after buying my first paper edition here in the States! Great service!

I also want to direct a comment to Robert Penfold on his 32-bit Output Port project (*Interface* Oct '01) using the UCN5818AF. As he mentioned, this chip was designed for fluorescent displays, but I want to add that this chip also opens up exciting possibilities for designing nixie tube projects (you remember nixie tubes – those orange neon numeric display tubes so popular for a brief time before I.c.d.s came out).

Before this chip and those like it were available, either high voltage transistors (10 per tube) or the ultra illusive and high power 7441 I.c.s were needed to pull the high voltage cathodes down to light the numerals. The 5818 not only provides this ability, but its simple serial interface makes it a snap to design a nixie display or

clock without separate shift registers or tons of output ports. 32 bits just happens to be perfect for clock numerals, and with free samples available from Allegro Microsystems (www.allegromicro.com/ or www.allegromicro.com/sf/58184/index.htm) you can bet that a nixie clock will be my first project once I get my *Mk3* built! Say, that might make for a great project writeup or submission to *Ingenuity Unlimited*.

Warren Parks,
Fort Collins, Colorado, via email

Great effusion and great to hear from you Warren! I've passed your comments to Robert and added you to my fan club list – welcome aboard!

I remember nixies very well, and had lots of fun with them, even believing that by using four in a display plus some flip-flops built using many discrete transistors etc, copying a circuit in a Mullard book, I was on my way to designing a computer (very early 60's I think – how naive!).

Ingenuity Unlimited is always pleased to receive interesting offerings.

TK3 AND PARTITIONED DRIVES

Dear EPE,

I notice through various *Readouts* that some readers have tried to install TK3 on a partitioned drive but failed. I had problems trying to get TK3 to run on my second (of two) hard drives (D:) with the following results and "fixes":

When trying to run the program on D: – from a shortcut on the desktop – I kept getting a "path not found error" when the program tried to open its first text file, i.e. *TK3Settings.txt*. I eventually found that the default drive and path were still pointing to drive C:. The way I got around this was to insert the following two statements in the *TK3MainProgram* Form Load sub() after the third line:

ChDrive App.Path "Change to the drive on which the application is running"

ChDir App.Path "Change to the application's directory"

This change allowed the program to be loaded on either drive and to run in that drive provided that there was a copy of the program on the respective drive. There is more information in VB help under App.

There was also a problem when trying to change drive from within the TK3 Check Toolkit PCB Functions screen. Changing to drive A: was OK but trying to change back to C: or D: gave "Runtime error 76, Path not found". This I eventually traced to the fact that *Drive1.Drive*, in the case of hard drives, returns both the drive and its label. The solution seems to be to change the first line in *TK3CheckToolkit* sub *Drive1_Change()* to `DefaultDrive Left(Ucase$(Drive1.Drive), 2) & "\\"`

thus picking up only the drive letter and not the Volume-id. There is information in VB help under *DriveListBox* control, drive property, and then scan to Fixed Media.

Thank you for pointing out the existence of *NoteTab*. I have not used it very much as yet but it seems to be just what is wanted.

Now the main point of my visit to your site was to see if there was any help about running TK3 under Windows XP. I found your compilation notes on the subject in the ftp TK3 folder, downloaded a copy of the Sybera product and am now able to run TK3 under XP successfully. I followed the notes written by Peter Shew, for which he, and the other contributors, is to be much thanked.

Many thanks for your Herculean efforts with all the various PIC projects. I find them all very absorbing and I am looking forward to reading all about interrupt programming.

Colin Birtwistle, Swanley, Kent

Thanks Colin for the Drive information, I'll look into adding it to TK3 for general release.

With XP now so firmly on the scene (and I've yet to hear any good reports about it), it's useful to know that there is a fix to using TK3 with it. Why on earth have Microsoft made it so hard to communicate with the outside world via printer ports? In this respect, machines of 20 years ago were better suited, having such things as "user ports".

CAPACITANCE METER

Dear EPE,

The *Capacitance Meter* in Nov '01 was interesting but to say that it allows any capacitor type to have its true value readily measured and displayed is totally inaccurate and could be very misleading. In fact, as an electrolytic capacitor ages and starts to dry out its capacitance value becomes much more frequency dependant. A worn capacitor may be perfectly OK smoothing a 100Hz ripple in a linear regulator, but the same capacitor fitted to a switch mode power supply working at a switching frequency of 15kHz could be totally useless, even open-circuit if tested at that frequency.

It should be pointed out that a fresh new capacitor does not exhibit this phenomenon to such a large degree, it may only fall in capacitance by a few microfarads. Old worn capacitors are also very temperature dependant, such a capacitor may test OK at room temperature, but cool it down with a can of freezer and it can fall to zero. While your design may be good in principle it cannot be considered as an accurate test to apply to an electrolytic capacitor.

A much better test to apply to an electrolytic capacitor is to measure the capacitor's "effective series resistance" (ESR) in ohms using a special-ist tester. This test is usually applied by the tester at a frequency of 100kHz and is a measure of the capacitor's goodness. The test is applied to the capacitor in circuit and can give an early indication of capacitor failure.

In my job as a TV video engineer I quite often find that a faulty electrolytic removed from a switchmode power supply can read OK when checked on my professional digital capacitance meter. In-circuit capacitor ESR testers are readily available from various sources from around £130. Once you've used one you will wonder how you ever managed without it. Perhaps you should consider an ESR meter project.

Incidentally, I started reading your magazine in 1976 at the age of 11.

**Michael Dranfield,
Buxton, Derbys, via email**

Editor Mike says that we'll see what we can do about an ESR meter. There is also a build-yourself one in Supplement S57 of our sister publication Electronics Service Manual. Stay reading good publications!

PIC SPECTRUM ANALYSER

Dear EPE,

The *PIC Spectrum Analyser* is yet another really excellent project from John Becker – how does he find the time?

I have been a *PE* (and then *EPE*) reader since the first one in 1964 (when I was 14) and it really does lead all other publications in that it is fully informative, has excellent projects, includes all software (to allow user modification, which is what good projects are all about – unlike your competition). You keep a nice blend of starter through to high end type of projects such as this month's *Spectrum Analyser*.

I especially like the PIC projects as I use PICs throughout – one constructive comment, if I may: I would really recommend using MPASM as it includes a good IDE/text editor, software emulation, etc. I know you can transfer from TASM but why re-invent the development tools when Microchip provide them for free and update as necessary!

I fully appreciate the need to put the magazine on the web. However, in the future, please do not stop the option of still purchasing it in its current form as a paper magazine can be carried around, read on the bus/train, etc. (I know you can do a printout but it is not the same!)

**Stephen H. Alsop,
via email**

Nice of you to offer compliments on my Spectrum Analyser! Timewise, designing projects for EPE is a hobby I greatly enjoy because it keeps me out of the cold during the winter (but I'm longing for outdoors and summer!).

In fact, designing does not take as long as some of you might suppose. If you study my designs you are likely to find that there are aspects that might have originated in an earlier project, either as hardware or software. As I've frequently commented, much of electronics is based on "building blocks". That's one reason why EPE is so popular; many readers know that even if they do not want to build a design in its entirety, it can still be a useful source of ideas for other circuits that readers want to design.

It's really no different for my designs, and I often "re-vamp" some aspects as "library" material. This is especially true with software. Having worked out a routine for something, it can easily be used in another program that has a similar requirement, sometimes without modification, at other times with a variety of "tweaks" to tailor it to the new conditions.

Regarding MPASM, yes that's the dialect route I would recommend to anyone newly getting into PICs. The use of TASM is historical as that's the dialect introduced to us in the first PIC programmer design we did, in Feb '96. Having learned PICs through that article, TASM continues to be the dialect I prefer for myself, and I know lots of other people are also more familiar with TASM. That's why my TK3 caters for both dialects (it's also faster than I find Microchip's program to be). There's room for many PIC dialects, and readers no doubt choose the ones that are best suited to themselves. Many readers much prefer to write PIC programs in C, for example.

We thoroughly share your view that EPE should continue to be paper-based!

SOLDERING

Dear EPE,

I found your web site on soldering, and I think it's great. I'm a novice to this, and I fix Playstations. I have a 30W iron, but I seem to have a bad habit of scorching the circuit boards, and once, I accidentally removed a transistor that I wasn't supposed to, from the heat of the iron. I'm wondering if I should go to a lower-wattage iron, or if there is something else I'm doing wrong? Although I just found out my mistake in using the iron to move the solder. I also have no stand for the iron (I use a metal plate), but I do use flux.

Angela McGann, via email

Circuit Surgeon Alan is our soldering guru and replies:

30 watts is a little on the high side, especially if it's not temperature controlled. It's not too bad, but 15 watts would be fine for delicate Playstation-type work. I used a 15W iron for years till I could afford a proper soldering station.

A cheap stand would be a good idea. Electronics solder already contains its own flux and you must NEVER add flux separately, especially acid flux that e.g. plumbers use! It's the flux that helps the solder flow properly, and it's already inside the solder wire. That's the brown stuff you see bubbling off the solder.

It takes roughly 0.5 seconds or less to melt an average solder joint, you shouldn't keep heating the joint or you'll damage the board by making the copper foil tracks lift away from the circuit board. If you're scorching or blackening it then you're overheating it way too much!

It takes practice, I would get an old board and practice taking parts off, and soldering new parts in. You'll get the hang of it. Remember, you're only using the iron to briefly heat up the place where you're going to dab the solder onto, nothing else.

Alan Winstanley

SHORTENED DIVISION

Dear EPE,

Thanks to Peter Hemsley for his comments (Cheats Again, *Readout* Feb '02). There is always a trade-off in either performance or memory when making code generic but I'm sure most

people will agree that usually the benefits in flexibility outweigh the performance deficits. Therefore the full 16-bit division routine would be more useful as generic code than a 10-bit. Granted, if you were only going to use it for processing the 10-bit ADC on the PIC16F877, it is worth making a specific routine.

However, the following piece of code helps to optimise the full 16-bit division routine when being passed numbers less than 16-bit. I've taken the liberty of attaching the code and an explanation.

In the code to reduce cycle time when dividing smaller numbers, two bytes are still used for the dividend (the program may not always know how big the numbers are!). My piece of code simply checks the dividend's upper byte to see if it is zero or not. If it is, the upper and lower bytes are swapped and the count reduced by eight. This saves eight redundant Rotations Through Carry. Then the code snippet checks for leading zeros. Once again, if any of these are shifted round and the bit count reduced without the unnecessary comparison part of the algorithm executing.

Part of Peter Hemsley's original:

```
divide movfw divisL
iorwf divisH,w
skpnz
goto div0      Division by zero !
movlw 16       16 bit division
movwf bitcnt
clrf remdrH
clrf remdrL
```

My piece of code:

```
movfw dividH
btfss STATUS,Z test high byte for any set
bits
goto leadoff
movfw dividL    high byte of dividend
empty
movwf dividH    swap the two bytes
clrf dividL
movlw 8
movwf bitcnt    make the count just 8
this would cut down the
number of iterations to 8
leadoff btfsc dividH,7 now remove the leading
zeros
goto dloop
clrc
rlf dividL
rlf dividH
decf bitcnt
goto leadoff
```

Peter's code again

```
dvloop clrc      Set quotient bit to 0
rlf dividL       Shift left dividend and
quotient
rlf dividH       Msb into carry
rlf remdrL       and then into partial
remainder
rlf remdrH
(etc)
```

Gerard Galvin, via email

Thanks Gerard, that seems interesting, I'll add it to the PIC Tricks ftp and disk.

TK3 AND PICTUTOR

Dear EPE,

I am sure you had no intention of misleading Tomas Henry in your reply (Jan '02) but I have tried using your brilliant TK3 software with the PICTutor board and apart from being confined to 14-pin PICs of the 16x84 variety and not being able to disassemble to ASM, it worked perfectly without any modification to the hardware.

Pat Alley, via email

Thanks Pat, but I took it that Tomas wanted to know if TK3 was fully usable with PICTutor – which it is not. Providing PICTutor users perform the correct on-board switch operations at appropriate points before and after programming, TK3 can indeed send programs to PIC16x84 devices on the Tutor board.

ELECTRONICS CD-ROMS

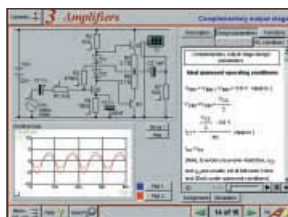
ELECTRONICS PROJECTS



Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation and p.c.b. design** software is included. The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ANALOGUE ELECTRONICS

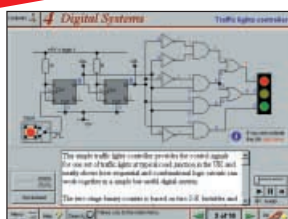


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits. Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

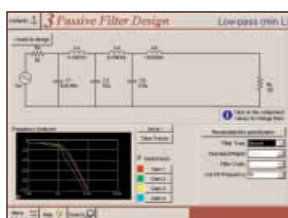
NEW VERSION 2



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen. Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

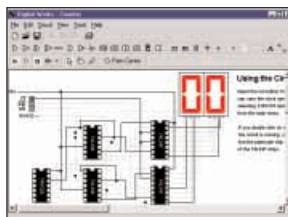
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

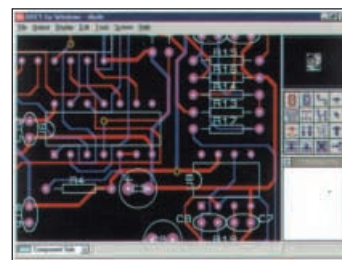
DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability. ● Software for simulating digital logic circuits. ● Create your own macros – highly scalable. ● Create your own circuits, components, and i.c.s. ● Easy-to-use digital interface. ● Animation brings circuits to life. ● Vast library of digital macros and 74 series i.c.s with data sheets. ● Powerful tool for designing and learning.

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots, etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

“C” FOR PICMICRO MICROCONTROLLERS



C for PICmicro Microcontrollers is designed for students and professionals who need to learn how to use C to program embedded microcontrollers. This product contains a complete course in C that makes use of a virtual C PICmicro which allows students to see code execution step-by-step. Tutorials, exercises and practical projects are included to allow students to test their C programming capabilities. Also includes a complete Integrated Development Environment, a full C compiler, Arizona Microchip's MPLAB assembler, and software that will program a PIC16F84 via the parallel printer port on your PC. (Can be used with the *PICtutor* hardware – see opposite.)

Although the course focuses on the use of the PICmicro series of microcontrollers, this product will provide a relevant background in C programming for any microcontroller.

PRICES

Prices for each of the CD-ROMs above are:

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(UK and EU customers add VAT at 17.5% to “plus VAT” prices)

Interested in programming PIC microcontrollers? Learn with **PICtutor**



The Virtual PIC

This highly acclaimed CD-ROM by John Becker, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject. Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

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Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials. The **Deluxe** Development Kit is supplied with a plug-top power supply (the **Export** Version has a battery holder), all switches for both PIC ports plus I.C. and 4-digit 7-segment I.E.D. displays. It allows users to program and control all functions and both ports of the PIC. All hardware is supplied **fully built and tested** and includes a PIC16F84.

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HARDWARE

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Deluxe PICtutor Hardware

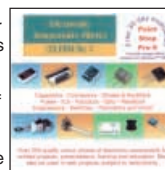
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ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

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VERSION 2

ELECTRONIC CIRCUITS & COMPONENTS V2.0

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Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

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VERSION 3

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME/XP, mouse, sound card, web browser.

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SOLAR CHARGE AND GO



TERRY DE VAUX-BALBIRNIE

Keep mobile while enjoying the outdoor life!

SOME people shun traditional sun-and-sand holidays to seek the independent life. Carrying a small tent and a minimum of equipment on their back they walk, climb, camp, and fish to get as close to nature as they can.

So what self-respecting independent traveller would carry a mobile phone? Apparently, many do. Some simply wish to maintain contact with family and friends at home. Others see it as an important piece of safety equipment that may be used to summon help in an emergency.

However, there is a problem. Once the phone battery has run "flat", it may be impossible to charge it. With no mains or 12V (car) supply available, use of the phone may be restricted to emergency use only and kept switched off most of the time.

Even so, the battery (depending on type) will self-discharge fairly quickly. On a long trip, it may be found that it has discharged whether the phone has been used or not.

O SOLAR MIO

This solar-operated circuit will charge a nominal 2.4V or 3.6V nickel-cadmium or nickel metal hydride mobile phone battery. It may also be used to power an inexpensive 3V personal cassette player (the type that normally use two AA-size cells). You could listen to music or learn the local language! Note, however, that the unit will probably *not* be successful at operating the cassette player and charging the mobile phone battery at the same time.

Many mobile phones use the batteries above. For example, the popular Nokia 3210 and 5110 models use a 2.4V and a 3.6V type respectively.

Before starting any construction work, check the voltage of your battery by looking at the label attached to it or by measuring the voltage directly using a multimeter. If doing this, *take great care to avoid short-circuiting the terminals*. Note that a fully charged battery will have a terminal voltage a little higher than the stated value (2.6V approximately for the nominal 2.4V variety).

This circuit is *not* suitable for phones that use a *higher* voltage than 3.6V. Also, it has not been tested on batteries other than the nickel metal hydride (NiMH) and nickel-cadmium (NiCAD) type.

If you decide to devise some means of attaching the unit to the top of your backpack (to maximise the amount of light reaching it), remember that, as described, it is not weatherproof. It would therefore be necessary to waterproof it yourself or pack it in a dry place when it rains. Remember also that the solar cells and meter used will not withstand too much abuse such as dropping them on the ground.

TO THE EDGE

The unit is built in a plastic box with two solar panels, an edge-type meter and a light-emitting diode (l.e.d.) mounted on top. The meter monitors the current provided by the solar panels and helps the user to align the unit for maximum illumination.

Inside the box, there is a circuit panel and two sets of AA-size cells in holders. One comprises three re-chargeable cells and the other, three of the "throwaway" alkaline variety. The re-chargeable cells provide a reserve of energy collected by the solar panels which may then be used to operate the personal stereo. They also have an important voltage stabilising effect which will be explained later.

On the rear panel of the unit are two switches and two output sockets. One

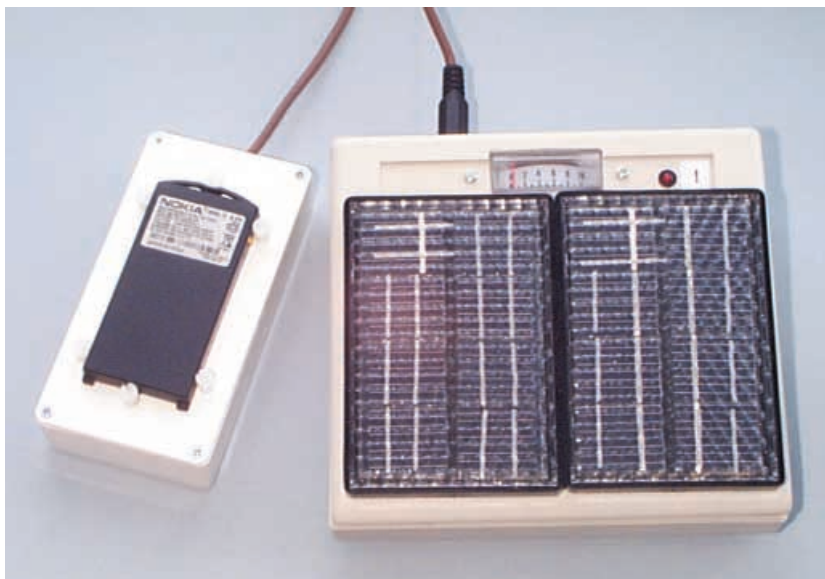
socket is used for mobile phone battery charging and the other to power the personal stereo. The sockets are of different types so make sure only the correct one is used for the job because they are not interchangeable.

One switch sets a "high" or "low" charge rate for the re-chargeable batteries (the purpose of this will be explained later) and the other selects "normal" or "backup" mode for the mobile phone battery. When the backup supply is switched on, the light-emitting diode on top glows to remind the user that this has been done.

BACKUP SUPPLY

The backup supply is provided by the alkaline cells. These enable the mobile phone battery to be kept sufficiently charged for an emergency call to be made. This will be useful when there has been insufficient light to keep the battery charged using solar energy alone or if the phone has been used excessively.

Regarding mobile phone battery charging, initial tests were made using the existing charger input on the phone. This proved unreliable due to the voltage drop of the internal voltage regulator and the checks made by the phone circuit. Also, all the various models of phone could not be tested. However, good results are obtained by removing the battery from the phone



and placing it in a separate small holder which is plugged into the appropriate output socket.

It would be a good idea to buy a second battery so that the phone may be kept in use while the other one is on charge. In fact, it would be best to buy two inexpensive "compatible" (non-manufacturer's) batteries and keep the original one for home use. This is because charging by the present unit is not as sophisticated as that provided by the phone itself and a conventional plug-in charger. If carelessly used, overcharging could occur which might damage the battery.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Solar Charge and Go is shown in Fig.1. X1 and X2 are the solar panels which provide a nominal 3V at 80mA each (based on bright-light conditions). These are connected in series to give nominally 6V at 80mA. Tests show that the specified units will supply about 20mA under reasonably bright conditions and around 100mA in full sunlight.



Rear view showing the two function switches and two output sockets.

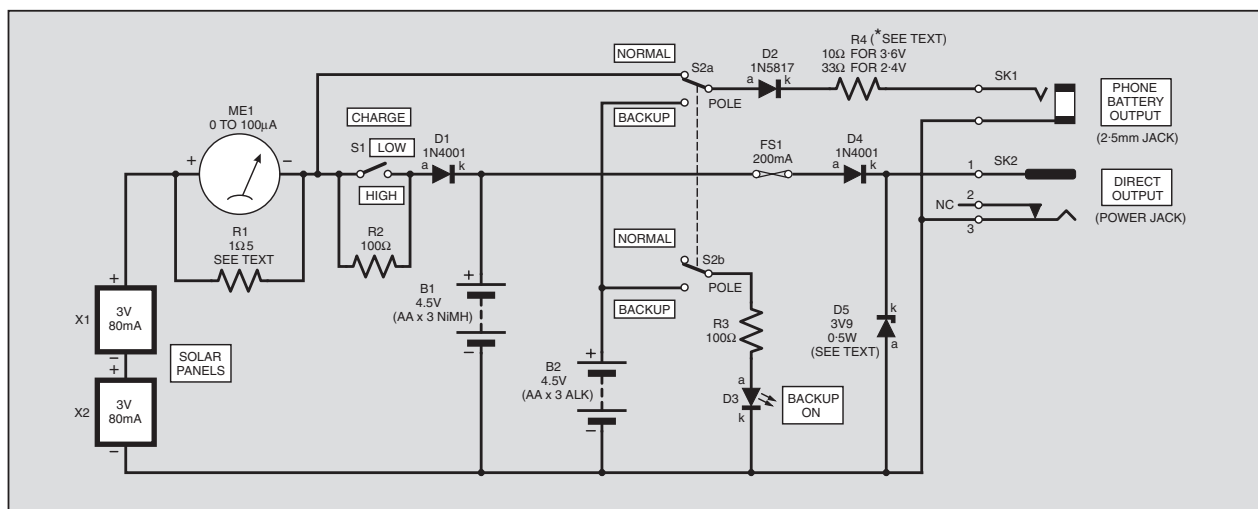


Fig.1. Complete circuit diagram for the Solar Charge and Go power unit.

As they stand, the solar panels would make a poor supply. The voltage and current-delivering capability would vary greatly with the brightness of the light reaching them.

In fact, it is quite likely that the output would be insufficient to operate a cassette player direct – those tested needed 150mA approximately. The re-chargeable battery pack will make up the shortfall and enable several hours of use per day depending on the available light. It will also enable the user to listen to music in the evenings!

Assume that Charge switch S1 is closed for the moment ("high" position). Assume also that nothing is plugged into either output socket, SK1 or SK2. Resistor R2 is bypassed by S1 contacts so has no effect.

The current from the solar panels passes through milliammeter ME1 (resistor R1 connected between its terminals provides the correct full-scale reading and this point will be explained later). It then flows through diode D1 to battery pack B1 (comprising three nickel metal hydride cells – NiMH).

Cells made using this technology, unlike the nickel-cadmium variant, do

not suffer from the "memory effect". This is a gradual loss of capacity when they are not completely discharged before re-charging. Due to the nature of this circuit, nickel metal hydride cells are more appropriate because they are more likely to be partially charged and discharged.

BATTERY VOLTAGE

The nominal voltage developed by the battery pack B1 is 3.6V (that is, 1.2V per cell) although this will rise to some 4.1V when fully charged and off-load. Unless conditions are very cloudy, the voltage available from the solar panels (even taking into account the forward voltage drop of diode D1) will exceed that of the re-chargeable cells. The cells will therefore charge up over a period of time. Diode D1 prevents them discharging back through the solar panels when there is insufficient illumination.

When switch S1 is set to the "low" position, the current from the solar panels must now flow through resistor R2 and this limits it to a smaller value. This may pass continuously through B1 cells and will simply maintain the charge.

PHONE OUTPUT

With switch S2 in the "normal" position, current will pass from the solar panels, meter ME1, S2a contacts, diode D2 and resistor R4 to a mobile phone battery plugged into socket SK1. The battery will then charge in a time dependent on the light available. Diode D2 is a Schottky barrier diode which has a smaller forward voltage drop (0.3V rather than 0.7V for a conventional silicon diode) so involves less loss in the charging process.

Assuming switch S1 is set to "high", the voltage appearing at diode D1 anode (and hence at D2 anode) will be some 0.7V (its forward voltage drop) higher than that at B1 positive terminal. It will therefore lie in the range 4.3V to 4.9V (assuming sufficient light reaches the solar panels to allow this to happen). This provides a reasonably stable supply to charge the phone battery.

The value of resistor R4 is chosen according to whether a 2.4V or a 3.6V battery is being charged. This limits the current to a reasonable value. In the prototype unit, this was some 50mA to 60mA. This is kept on the low side on purpose to prevent damage.

WIRED FOR SOUND

A personal cassette player is operated by plugging it into socket SK2. The unit receives some current from the solar panels which is then "topped up" by battery pack B1. If the ambient light level is low (say, at night), all the current is supplied by the batteries.

The current flows through fuse FS1 and diode D4. In the event of a short circuit, rechargeable cells can deliver a very large current and this could cause the wiring to become hot and possibly for the insulation to burn. The fuse FS1 is included to prevent this happening.

Since the nickel-metal hydride cells (B1) "lock" the voltage appearing across them to 4.1V, there will be some 3.4V available at output socket SK2 taking into account the forward voltage drop of diode D4. However, this falls to 3V or less (2.6V in the prototype unit) under the load of the cassette player.

Equipment normally powered using two "AA" size cells should be designed to operate with an applied voltage as low as 2.4V or less (allowing it to be used when the batteries have run down to some extent) and as high as some 3.3V (that is, 1.65V per cell which is the approximate voltage developed by new cells). The supply at socket SK2 should therefore operate the cassette player correctly.

MODIFIED READING

Returning to meter ME1, the specified unit has a full-scale deflection of 100µA yet the maximum current in the circuit is likely to exceed 100mA. The full-scale reading therefore needs to be modified and this is the purpose of "shunt" resistor R1.

A shunt is a low-value resistor, which allows most of the current to flow through itself and only a small amount through the meter. By choosing a suitable value, it can be arranged for a total current of, say, 120mA (rather more than the maximum delivered by the solar panels) to allow 100µA to flow through the meter (and so give a full-scale reading).

The value of the resistor required depends on the basic full-scale deflection (f.s.d.) of the meter and its resistance. The specified unit has a resistance of 1750 ohms. Calculation shows that for a full-scale deflection of 120mA, a suitable value for the shunt resistor is 1.5 ohms. The value may be modified to make it suitable for other meters and solar panels. This can be done by trial and error and is described at the end.

When switch S2 is in the "backup" position, S2a connects the reserve supply to socket SK1. At the same time, S2b contacts connect "backup" i.e.d. D3 in circuit with current limited by resistor R3. Of course, you could omit the i.e.d. to save power but care would then be needed to switch back to "normal" as soon as possible.

LOCK ON

Normally, a cassette player will have its input voltage limited by the nickel metal hydride cells. It therefore remains more or less constant whatever the intensity of light reaching the solar panels.

Should a fault develop whereby B1 becomes disconnected (due to, say, one of the cells dislodging from its holder or to a

COMPONENTS

Approx. Cost
Guidance Only
excl. case, meter & batts.

£29

Resistors

R1 1k25 (see text)
R2,R3 100Ω (2off)
R4 33Ω (for a 2.4V phone battery) or 10Ω (for a 3.6V battery)

All 0.25W 5% carbon film.

Semiconductors

D1, D4 1N4001 50V 1A diode (2off)
D2 1N5817 Schottky diode
D3 3mm red i.e.d.
D5 3V9 0.5W Zener diode

Miscellaneous

X1, X2 3V 80mA (nominal) solar panels – see text (2 off)
ME1 100µA f.s.d. edge panel meter. 1750 ohms coil resistance (see text)

See
SHOP
TALK
page

SK1 2.5mm panel mounting socket
SK2 power-in type panel mounting socket
S1 s.p.s.t. toggle switch
S2 d.p.d.t. toggle switch
B1 AA-size nickel metal hydride cells (3 off)
B2 AA-size alkaline cells (3 off – see text)

Tag board: two rows of 6 tags (or alternative method of construction); plastic box size 254mm x 203mm x 40mm (max height) x 20 (mm height); holders for three AA cells (2 off); battery connectors (2 off); 3mm i.e.d. clip; power-in type line plug; 2.5mm line plug; possible dummy AA cells (see text – Fig.3); materials for phone battery charging unit (see text); small hardware.

soldered joint failing) the "locking" effect is removed. The supply will then rise to that of the solar panels less the forward voltage drop of diodes D1 and D4. This will exceed 6V off-load under bright conditions.

Since the solar panels cannot supply more than 80mA to 100mA this will probably be insufficient to operate a cassette player. The effect will be that the on-load voltage will fall below the operating value and it will simply stop working.

However, this cannot be guaranteed. If the unit requires less than 100mA, under such fault conditions it could prove destructive. To give an extra margin of safety, a 3.9V Zener diode (D5) is included.

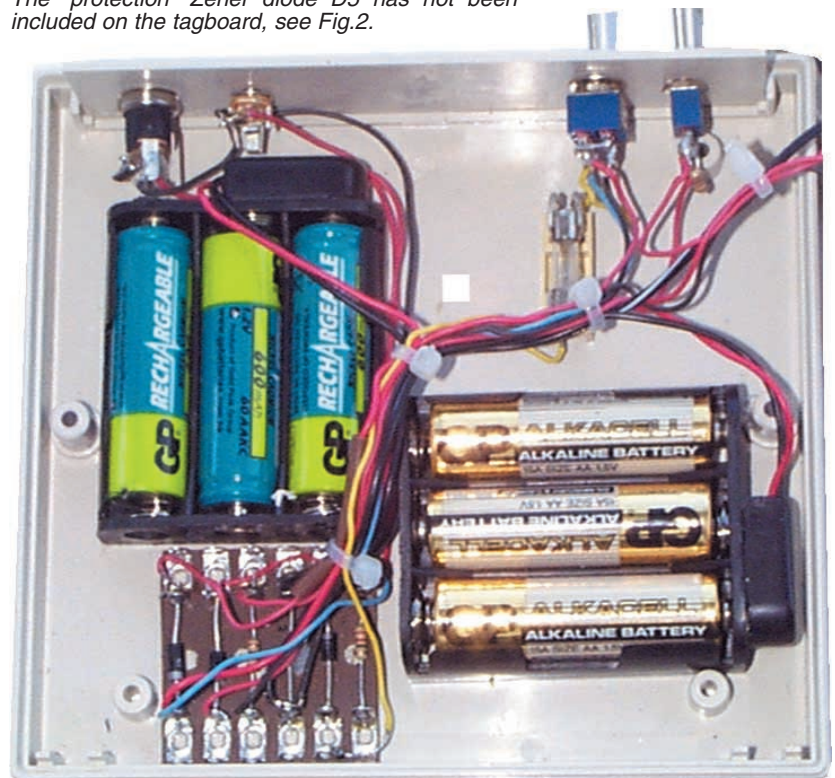
Even so, this over-voltage could prove too much, so to be safe, *only cheap equipment should be connected to this unit.*

CONSTRUCTION

The "tag board" method of construction shown in Fig.2 was used in the prototype. However, a stripboard layout could also be used. In view of the small number of components, a printed circuit board (p.c.b.) was not considered necessary.

Solder the components on to the board taking particular care over the polarity of the four diodes. Solder resistor R1 directly across the meter ME1 terminals and resistor R2 across switch S1 normally-open ("make") contacts.

Prototype interior layout and wiring inside the case. The "protection" Zener diode D5 has not been included on the tagboard, see Fig.2.



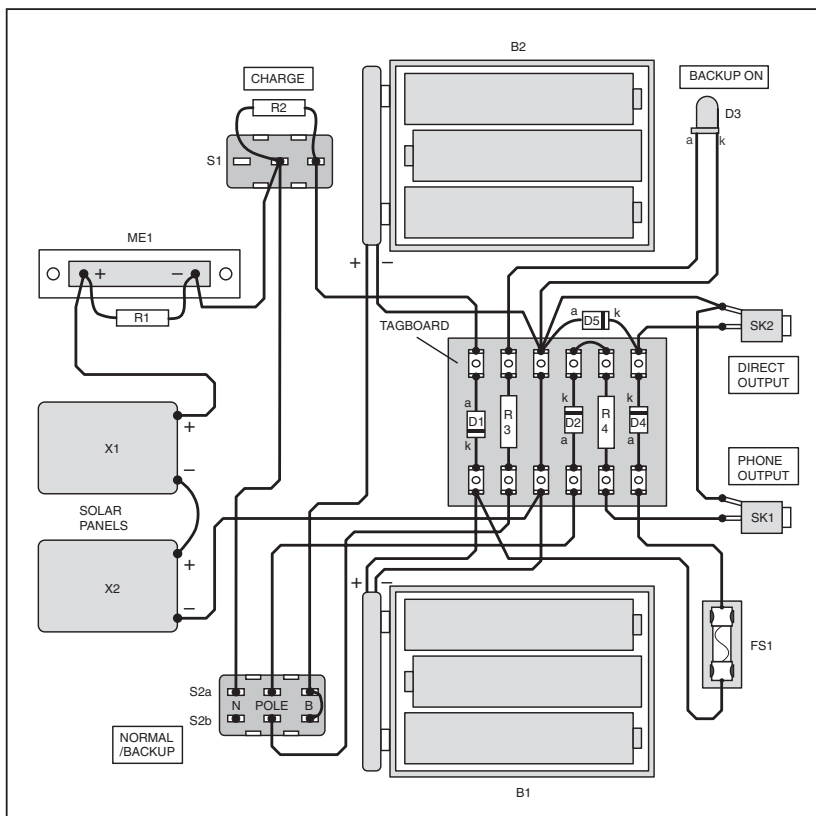


Fig.2. Tagboard component layout and interwiring details to off-board components.

The solar panels used in the prototype work well. However, others may be just as suitable. A single nominal 6V unit providing around 80mA should be satisfactory or a combination of individual solar cells connected in series or in parallel to provide a similar output.

PREPARING THE PANELS

Drill holes in the case for the solar panel wires also for mounting the meter, i.e.d. clip, switches, output sockets, battery holders and circuit panel. Note that miniature toggle switches were used in the prototype unit but it would be better to use slide switches if there is a chance that these could be operated unintentionally.

Attach the circuit panel and all other parts. If using the specified solar panels, cut the connecting leads to a suitable length. One of these has a stripe and, in this case, it denotes the negative (0V) one. Secure the solar panels using adhesive fixing pads.

Refer to Fig.2, and complete the internal wiring using light-duty stranded connecting wire. Sleeve the soldered joint which connects the solar panels in series. When wiring the sockets, make the "pin" (centre) connection the positive one in each case. The photograph shows the completed interior of the prototype unit.

BATTERY HOLDER

To charge the mobile phone battery, you

will need to make a small separate unit, which will allow the connections to be made to it. The photograph shows a Nokia 3210 battery but the exact details will depend on the unit used and will need to be modified with regard to its dimensions and the position of the terminals.

The unit is made from a thin plastic box rather larger than the size of the battery. Place the battery on the top panel and draw round its outline. Mark the position of the six circular plastic p.c.b. spacers 5mm long (or as appropriate) which act as location pegs. They should be positioned so that, when attached, the battery is held firmly.

When satisfied about the positions, drill the holes and attach the spacers. Check that the battery will locate accurately and make adjustments as necessary. Remove the battery, measure and mark the position of its terminals and make a small slot in the lid to correspond.

MAKING CONTACT

Contact with the battery terminals may be made in various ways. However, there should be some form of spring loading to ensure reliable contact.

In the prototype unit, two sub-miniature lever-arm microswitches were used. It was only the spring action and ease of mounting which was required – not the actual switches. The levers were carefully bent through right angles to provide tips which passed through the slot to make contact with the battery terminals.

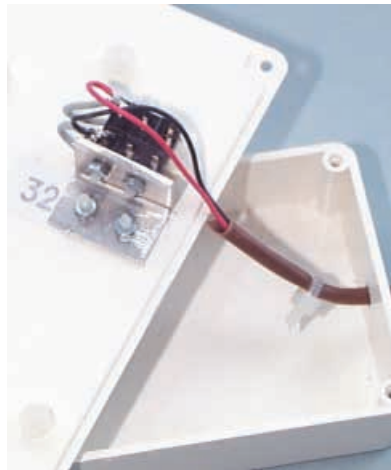
The correct spacing for the prototype battery terminals (5mm) was obtained by attaching the switch bodies together and these were, in turn, mounted on a small aluminium bracket. Thin flexible wires were tightly twisted on to the pivot end of the arms (soldering could possibly damage them). The other ends of the wires were soldered to one of the switch terminals in each case to provide "take off" points.

Connections from here were made to the wires which passed through a hole in the box. A cable tie was used to provide some strain relief to the wire and prevent the connections becoming dislodged if it was pulled in service.

A 2.5mm mono jack plug was then soldered to the other end. Take care to observe the polarity so that the positive



Lever-arm microswitches used for battery contacts in the prototype battery holder unit.



Interior of the battery holder showing the aluminium microswitch mounting angle bracket.



The mobile phone battery mounted on the battery holder contact box, between the locating pegs.

terminal of the battery leads to the "pin" connection of the plug. Also, take care not to cause a short-circuit inside the plug since this would damage the phone battery when this was in position. Check that the battery terminals make proper contact.

In the prototype, the plastic clip at the top of the battery ensured that it was held securely in the unit. However, in some cases a rubber band may be needed.

FULL-SCALE READING

The value of shunt resistor R1 may be modified, if necessary, so that the meter reads near to full-scale deflection in full sunlight. To increase the reading, increase the value of R1 and vice versa.

If it is necessary to make a change, temporarily de-solder the solar panel positive wire from the meter terminal. This is because even a small current could damage the meter.

TESTING

Allow the nickel metal hydride cells to charge for a few hours in bright light (longer under cloudy conditions). Next, make up a connecting lead for the cassette player. This will be easy if it has a 3V input socket.

Failing this, you could use "dummy batteries". Their real purpose is to take up unoccupied space in battery chargers so the terminals are connected end to end.

To use them for the present purpose, the metal strip which forms this connection will need to be cut through and a small section removed. Connecting wires may then be soldered to the cut ends (see Fig.3). Attach the correct type of plug on the other end observing the polarity. Connect the cassette player up and check that it works correctly.

Allow the phone battery to run down (by leaving the phone switched on until it cuts out, **not** by connecting an artificial load to it). Now check that the backup supply can put sufficient charge into the battery to make a short call. A typical time needed to do this is one hour.

Next, check that with bright light reaching the solar panels, the phone battery charges up to, say, the 50 per cent level in a few hours. Test the amount of charge by replacing the battery in the phone. Do not be deceived by the display. This will probably give a reading on the high side and take some time to settle down to the correct value.

OVER THE TOP

If the solar panels receive full sunlight for 20 hours approximately with nothing plugged into either output, the re-chargeable cells could be overcharged (assuming they start from "flat"). This would damage them over a period of time.

To prevent such problems, set switch S1 to the "low" position after this time. However, if the unit is used to operate a cassette player every so often or if a mobile phone battery is being charged, the switch should be left set to "high".

With a reasonable amount of use, overcharging is not likely to occur. Avoid overcharging the mobile phone battery by

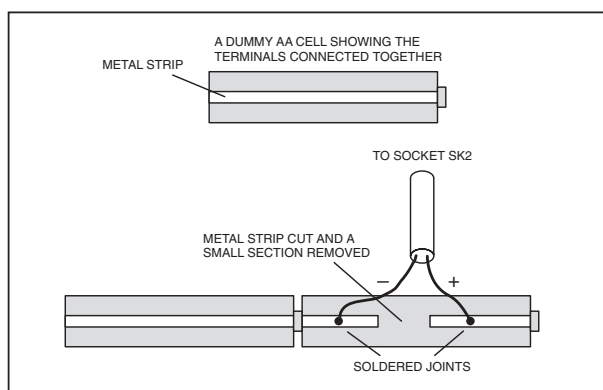


Fig.3. How two dummy cells may be used to make the connections to socket SK2 (sometimes the cells are used side by side).

leaving it in place for no longer than necessary.

Before the phone battery runs flat, make sure sufficient charge is put back (from the backup supply, if necessary) to enable an emergency call to be made at any time. It would be best to drain the phone battery by no more than can be put back during the course of one day.

With the phone simply switched on ("standby"), the current requirement is much less than while actually talking. It will be best to experiment with all this before you leave home. It would also be a good idea to carry a spare set of back-up batteries.

When setting out on a trip, start with the re-chargeable battery pack fully charged. Remember to replace the alkaline cells before your next trip – especially if they have been used.

Enjoy your holiday!



SHOP TALK

with David Barrington

PIC Controlled Intruder Alarm

The miniature 4x4 matrix data entry keypad used in the prototype *PIC Controlled Intruder Alarm* came from RS and can be ordered through any bona-fide stockists, code 331-304, including some of our component advertisers. You can order direct (credit card only) from **RS** on **01536 444079** or through the web at **rswww.com**. A post and packing charge will be payable. Other keypads can be used, but you will need to make sure the pin numbering corresponds with the circuit diagram or be prepared to change the wiring.

For those readers unable to program their own PICs, a ready-programmed PIC16F877 microcontroller can be purchased from **Magenta Electronics** (☎ **01283 565435** or **www.magenta2000.co.uk**) for the inclusive price of £10 each (overseas add £1 p&p). They are also able to supply a suitable 2 line x 16 characters per line alphanumeric display module at a very reasonable price.

The software is available on a 3.5in. PC-compatible disk (*EPE* Disk 5) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 301). It is also available Free from the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/PICAlarm**.

The alarm printed circuit board is available from the *EPE PCB Service*, code 339. Finally, the alarm fittings, such as PIR sensors, bell and strobe etc., can be purchased from most DIY superstores.

Solar Charge and Go

The 3V solar panels used in the *Solar Charge and Go* model came from **Maplin** (☎ **0870 264 6000** or **www.maplin.co.uk**), code CJ37S. They also supplied the dummy AA cells, code YX92, and the, single hole fixing, 2.5mm panel mounting power socket, code JK10L. A suitable plug is coded H62S.

For the 6-way tagboard you could try **Greenweld** (☎ **01277 811042** or **www.greenweld.co.uk**) and **Chevet Supplies** (☎ **01253 751858**). If problems do arise finding a local source for the tagboard, **Maplin** (see above) list one as code FL11. You will need to cut it down to size. The Shottky diode 1N5817 is also listed by them as code JA46A.

The miniature edgewise 100µA f.s.d. panel meter was purchased from **Farnell** (☎ **0113 263 6311** or **www.farnell.com**) code 143-509.

Electric Guitar Tuner

We do not expect any problems to be encountered when sourcing the components for the *Electric Guitar Tuner* project. Certainly, the op.amp and timer i.c.s are stock items carried by most component advertisers. However, to keep the battery drain low you need to order a "low-power" version of the 555 timer chip.

To keep frequency drift, due to temperature changes, to a minimum, a high quality capacitor must be purchased for C4. A polycarbonate type would be the best choice here, but a polyester capacitor should give good results. Ceramic types tend to have inadequate short and long term stability and should not be used.

The 2-pole 6-way rotary switch used in the prototype is a Lorlin type and came from **Maplin** (☎ **0870 264 6000** or **www.maplin.co.uk**), code FF74R. Most of our component advertisers should be able to offer a similar type.

Teach-In 2002 – Lab 6

Only the Hall effect sensor devices could cause sourcing problems in this month's *Teach-In 2002* – *Lab Work 6* demonstration circuits. The Honeywell SS441A (unipolar) and the SS411A (bi-polar) magnetic sensors were ordered from **Farnell** (☎ **0113 263 6311** or **www.farnell.com**), codes 311-1477 and 311-1465 respectively.

The rest of the semiconductors should be readily available from most of our regular components advertisers.

Manual Stepper Motor Controller

We cannot foresee any buying problems when shopping for parts for the *Manual Stepper Motor Controller* project. A good range of low-voltage stepper motors are stocked by **Magenta** (☎ **01283 565435** or **www.magenta2000.co.uk**).

The 4-way 3-pole rotary switch **MUST** be a "make-before-break" type. The one in the model came from **RS** (see earlier), code 320-736.

PLEASE TAKE NOTE

PIC Virus Zapper

Page 187, Fig.7 and components list. It has come to light that the PIC Virus Zapper's voltage regulator IC1 has the wrong type number (two digits being transposed), it should be LP2950CZ.

If any readers have trouble finding this device, it is listed by ESR Components (Tel. 0191 251 4363 or **http://www.esr.co.uk**), code LP2950CZ-5.0. Rapid Electronics (Tel. 01206 751166), code 82-0680, and Farnell (Tel. 0113 263 6311), code 412-478, also stock this device.

Dog and Cat Scarer (Ingenuity Unlimited)

Page 163, Fig.2. The output (pin 3) and the trigger (pin 2) designations of IC2 should be swapped over.

Mar '02

Mar '02

PROGRAMMING PIC INTERRUPTS

MALCOLM WILES

Part 2

How to use Interrupts successfully with your PIC programs.

LAST month we discussed the basic concepts of using interrupts and showed a simple circuit using a PIC16F84 which would allow you to experiment with them. We conclude with further examples of what you need to know to use interrupts successfully.

EXPERIMENT 3

Load INTPROG5 into the PIC and reconnect your flying lead to pin RB0. This is a simple program to flash the l.e.d. on RA0 at about 1Hz. It also has the INTF interrupt enabled. When this is running OK take the wire connected to RB0 and hold it on PIC pin 15 (CLKOUT) (i.e. connect together pins 6 and 15).

The l.e.d. will stop flashing and remain either on or off, depending on how it was

when the wire was connected. Remove the wire from CLKOUT, and the l.e.d. will start flashing again. Take a moment to think what might be happening here before reading on. The code section relevant to this experiment is shown in Listing 5.

Actually, this one isn't so difficult. CLKOUT is generating a clock output that is running at the same rate as the instruction processing rate. Interrupts are therefore being generated at the instruction processing rate. Since there are 14 instructions in the ISR, interrupts are being generated at 14 times the rate that the PIC can process them!

LOOPING IN THE ISR

If interrupts are allowed to occur faster than the PIC can process them, then as

soon as one interrupt has been processed and the PIC exits its ISR, another interrupt will be pending and the ISR is immediately entered again. Since interrupts pre-empt the main program, the main program never runs and the PIC effectively loops in the ISR. Externally the PIC will appear to be "dead" or to have "hung".

The same thing will happen if, due to a software bug, the ISR fails to clear the interrupt flag bit for the event which caused the interrupt. On exit from the ISR, the PIC will see the flag bit still set, and will think that another interrupt is pending. So it will immediately enter the ISR again, *ad infinitum*. If you want to try this as an experiment, in INTPROG5 replace the instruction:

CLR: BCF INTCON,INTF

by: CLR: NOP

and see what happens.

Last month when discussing INTPROG4 we said that it was necessary for the ISR to read PORTB to latch the changed value in order to clear the RBIF flag, but we glossed over what would happen if this was not done.

Another ISR loop is the answer. The PIC will continue to assert RBIF while it detects that there has been a change even if software tries to clear it, and so the ISR will be called continually.

So, if you do have a play with interrupts, and find that you have an apparently dead PIC on your hands, check to see whether an ISR loop could be the cause.

RE-ENTRANCY

Readers who have followed the plot so far may be wondering: if interrupt events are happening faster than the ISR can process them, is the ISR itself interrupted when the next interrupt event occurs? The answer is no (almost).

When the PIC takes an interrupt and transfers control to Location 4, as part of this procedure it also clears the GIE bit. Thus, although the interrupt events still occur and the flag bit(s) still get set, no further interrupts can be caused.

The RETFIE instruction used to exit from the ISR sets the GIE bit again. So under normal circumstances the ISR is not re-entered if another interrupt occurs while it is being executed.

It would be possible for an ISR to set the GIE bit, and so potentially be re-entered,

LISTING 5. Main loop and ISR code for INTPROG5.

```

MAIN:  CLRF TMR0          ; clear internal clock count-up
       CLRF COUNT        ; clear ticks count
A2:    BCF INTCON,T0IF    ; clear the TMR0 wrapped flag
A1:    BTFSS INTCON,T0IF  ; has TMR0 wrapped yet?
       GOTO A1            ; no, loop till it has
       INCF COUNT,F       ; bump count of wraps
       MOVLW SPEED       ; about 10 bumps/sec at 2MHz clock
       XORWF COUNT,W      ; sets Z if COUNT = W
       BTFSS STATUS,Z     ; test Z
       GOTO A2            ; Z not set so COUNT <> SPEED
       MOVLW 1            ; wraps COUNT = SPEED so
       XORWF PORTA,F      ; toggle RA0
       GOTO MAIN          ; and repeat main loop
; Interrupt service routine
ISR:    MOVWF SAVEW       ; save W
       SWAPF STATUS,W
       MOVWF SAVES       ; save STATUS
       BANK0              ; ensure Bank 0 set
       BTFSS INTCON,INTF  ; test INTF
       GOTO POP           ; not an RB0 interrupt
; there is an INTF interrupt
       NOP                ; nothing to do for this demo!
CLR:    BCF INTCON,INTF   ; clear the interrupt
       INCF ICOUNT,F      ; bump count of interrupts
POP:    SWAPF SAVES,W      ; restore STATUS
       MOVWF STATUS
       SWAPF SAVEW,F      ; restore W
       SWAPF SAVEW,W
       RETFIE             ; exit ISR
    
```

LISTING 6. Section of INTPROG6.

```

; interrupt setup
MOVLW INTTMR      ; set the timer
MOVWF TMR0
BCF INTCON,T0IF    ; ensure timer flag is clear
BSF INTCON,T0IE    ; enable timer wrap interrupt
BSF INTCON,GIE     ; enable global interrupts

; main loop
MAIN:
    MOVF ISRCL,W    ; copy ISR low byte counter
    MOVWF COUNTL
    MOVF ISRCH,W    ; copy ISR high byte counter
    MOVWF COUNTH

; subtract last counter value from this counter value
; check that the result is positive or zero (produces no borrow)
    MOVF LASTL,W    ; load last counter low byte
                    ; into W
    SUBWF COUNTL,W  ; subtract current low byte
    MOVF LASTH,W    ; load last counter high byte
                    ; into W
    BTFSS STATUS,C   ; C set if last subtraction did not
                    ; borrow
    ADDLW 1          ; C clear so add 1 to W for the
                    ; borrow
    MOVF COUNTH,F    ; test if high byte is zero
    BTFSS STATUS,Z
    GOTO A2          ; Z clear so high byte not zero
    MOVF LASTH,F    ; COUNTH is zero, so test if
                    ; LASTH is zero
    BTFSS STATUS,Z   ; if it's not, H byte must have
                    ; wrapped
    GOTO A5          ; Z clear so LASTH not zero –
                    ; skip the check
A2:   SUBWF COUNTH,W  ; subtract LASTH from
                    ; COUNTH
    BTFSS STATUS,C   ; C set if there was no borrow,
                    ; so OK
    GOTO FAIL        ; C clear so an error has occurred

A5:   MOVF COUNTL,W  ; copy this counter to last counter
    MOVWF LASTL
    MOVF COUNTH,W
    MOVWF LASTH
    INCF LOOPCT,F    ; bump the main loop counter
    BTFSS STATUS,Z   ; skip if it has wrapped to zero
    GOTO MAIN        ; else repeat main loop
                    ; every 256 times round flash the led briefly
A1:   BSF PORTA,0    ; turn LED on
A3:   INCF LOOPCT,F  ; bump the counter
    BTFSS STATUS,Z   ; till it wraps to zero again
    GOTO A3
    BCF PORTA,0      ; then turn off the LED
    GOTO MAIN        ; and resume

; check has failed – put on the LED and loopstop
FAIL: BSF PORTA,0
STOP: GOTO STOP

; Interrupt service routine
ISR:  MOVWF SAVEW    ; save W
    SWAPF STATUS,W
    MOVWF SAVES      ; save STATUS
    BANK0            ; ensure Bank 0 set
    BTFSS INTCON,T0IF ; test T0IF
    GOTO POP          ; not a timer interrupt
                    ; there is a timer interrupt
    INCF ISRCL,F      ; bump interrupt count low byte
    BTFSS STATUS,Z    ; test if it wrapped to zero – skip
                    ; if not
    INCF ISRCH,F      ; bump high byte if low byte
                    ; wrapped
    MOVLW INTTMR
    MOVWF TMR0        ; reset the timer
    BCF INTCON,T0IF    ; clear the interrupt
POP:  SWAPF SAVES,W    ; restore STATUS
    MOVWF STATUS
    SWAPF SAVEW,F      ; restore W
    SWAPF SAVEW,W
    RETFIE            ; exit ISR

```

and there are specialist cases when this might have uses. However, setting GIE in an ISR would invalidate some of the techniques discussed in this article, e.g. Context preserving.

The PIC is not well suited to writing re-entrant code, as it lacks any support for structures such as dynamic data stacks which would be needed. This article is not going there, and readers are strongly advised not to, either!

EXPERIMENT 4

INTPROG6 uses the PIC's internal timer to generate interrupts at quite a high rate (about 5kHz), though not so fast that it causes looping in the ISR. Each time the ISR is entered it bumps (increments) a counter, which is 16 bits (2 bytes) long because a 1-byte counter would overflow very quickly.

The program's main loop monitors and checks this counter. Because of the high interrupt rate, it is possible that the main loop is interrupted several times each iteration, so the counts it reads are not necessarily contiguous. Therefore the check is that the value just read is greater than the value read on the previous loop.

It does this by subtracting the previous value from the current value. If the result of the subtraction is not positive or zero, then something has gone wrong. If a counter error is found, the main loop "loopstops" with the l.e.d. fully illuminated. Of course the 16-bit counter will

eventually overflow, and allowance has to be made for this.

The main loop periodically turns the l.e.d. on and off briefly as a visual check that it is running OK. It does this too fast for it to be perceived by the eye as flashing – the l.e.d. appears to be dimly illuminated if all is well.

Read through Listing 6 and make sure you understand it, then load and run INTPROG6.

By now you will not be too surprised to see that the l.e.d. comes on dimly, then after a few seconds is fully illuminated as the program detects an error in the counter. Murphy's Law has struck again – but exactly where, and how? What is the bug in INTPROG6?

Give up? OK, look at the four instructions following the label MAIN, which copy ISRCL and ISRCH to COUNTL and COUNTH. Consider what happens if an interrupt occurs after COUNTL has been copied but before COUNTH has been copied.

On first thoughts it would seem there is no problem. Let's assume for the sake of argument that ISRCL and ISRCH contain some arbitrary count like H'1234'. The first two instructions will copy H'34' into COUNTL. Then an interrupt occurs and ISRCL is incremented to H'35'. COUNTL will stay at H'34', and the main loop will then copy H'12' into COUNTH.

The program then checks the value H'1234', which will be found to be at least as large as the previous value. The last value

will be set at H'1234', and the next iteration will read the value H'1235' or larger, which will also check out successfully.

But now consider what will happen if ISRCL and ISRCH contain not an arbitrary value, but one where the low byte is just about to wrap, e.g. H'12FF'. COUNTL will be copied as H'FF'. Now the ISR runs and ISRCH/L are bumped to be H'1300'. So COUNTH is copied as H'13'.

The main loop checks that H'13FF' is greater than the last value it read, something like H'12FE' maybe, and indeed it will be. But it will set the last value read to H'13FF'.

On the next iteration it will read something like H'1300' or H'1301', but unless there have been 256 or more interrupts during one iteration of the main loop (which can't happen with the parameters of Experiment 4) then it will read a value less than the last one it has stored.

This is what is happening to INTPROG6 – it runs OK till an interrupt occurs which will cause the low byte to wrap and high byte to increment while it is in the middle of copying that value.

CRITICAL SECTIONS

It turns out that this is a very common problem. Most programs have sequences of code where they are manipulating several related variables together such that if they get interrupted during the sequence, the variables will be left in a half updated or inconsistent state.

Software engineers call these code sequences *critical sections*. What is needed is some mechanism to ensure that these critical sections are not interrupted but allowed to complete safely. The PIC, happily, provides a suitable mechanism. We've already met it: it's called the GIE.

The three instructions following MAIN in INTPROG6, which copy ISRCL and ISRCH, are a critical section. If the program is interrupted during this sequence then, as we've just analysed above, things can go wrong. And if they can go wrong, by Murphy's Law they will.

We need to prevent the program from being interrupted during this sequence. So we protect it by disabling interrupts before it and re-enabling them after it:

```
MAIN: BCF INTCON,GIE ; disable
      ; interrupts
      MOVF ISRCL,W    ; copy ISR
      ; low byte
      ; counter
      MOVWF COUNTL
      MOVF ISRCH,W    ; copy ISR
      ; high byte
      ; counter
      BSF INTCON,GIE ; enable
      ; interrupts
      MOVWF COUNTH
```

Now the ISR cannot be run during the copy, and we are guaranteed that COUNTH and COUNTL will be a consistent and correct copy of ISRCH and ISRCL. Once ISRCH is loaded into W we can safely re-enable interrupts because the ISR does not affect anything else used by the main loop. Any interrupt events that occurred during the critical section will cause the ISR to be run at this point, but the ISR will preserve W.

If you make the above changes to INTPROG6 and rerun it, you will probably find that it runs OK (i.e. with the dim l.e.d. on indefinitely).

So, are we finally done? Well, maybe not quite. Murphy may still have one more trick up his sleeve, and it's a subtle one. If we want to make our code really bombproof, we should protect against this too.

MURPHY'S LAST TRICK?

Earlier versions of the PIC16x84 data sheets identified a possibility that we shall now discuss. The relevant note has disappeared from later versions and is not in the '87x data sheets. In various tests the author has been unable to reproduce the behaviour described in this section with a PIC16F84, even using an external oscillator that is not synced to the instruction clock as interrupt source.

It would therefore appear that Microchip have fixed this "feature" in later versions of their microcontrollers. But since it's still possible that you might be using an old PIC, perhaps a 16C84, that behaves this way, it's as well to be aware of this problem and how to get around it. For safety it is advised that all programs for all PICs use the workaround.

Remember the quiz show *Mastermind*? When the time-up pinger went in the middle of a question, Magnus Magnusson would announce his catchphrase "I've started so I'll finish", and the contestant could complete the answer to that question.

So it is with the PIC; if an interrupt event occurs when an instruction has started, the interrupt is held pending until the instruction in progress has completed, and then the transfer of control to the ISR takes place. Instructions are sometimes said to be *atomic* with respect to interrupts, where *atomic* is used in its original Greek meaning of *indivisible*.

TURNING OFF INTERRUPTS

Now, instructions take some time to complete; typically four clock cycles on the PIC. The instruction has to be fetched from program memory, parsed and the opcode decoded. In the case of the BCF instruction, the operand has to be fetched from register memory, the appropriate bit cleared and the result written back to register memory.

An interrupt can occur at any time during this procedure. In the processing of the BCF INTCON,GIE instruction there could be a time window after the instruction has started and before the PIC has determined that the GIE bit is to be cleared when an interrupt event can occur.

If it does, the interrupt will be taken and held pending till the clear GIE instruction completes. Then the ISR will run, and will terminate with a RETFIE. But as we saw earlier, RETFIE sets the GIE bit. So when the main program resumes at the instruction after the BCF INTCON,GIE then GIE will be set and it will be as if the BCF instruction had not executed. We will be into our critical section with interrupts still enabled!

The bottom line is that a BCF INTCON,GIE instruction cannot be guaranteed to succeed if interrupts are enabled, as they usually will be if you're clearing GIE!

The workaround is simple: after a BCF INTCON,GIE you need to test GIE to ensure it really is clear, and if not go back and repeat the clear. Eventually it will succeed, unless you're in an ISR loop. The following sequence does the job:

```
MAIN: BCF INTCON,GIE
      BTFSF INTCON,GIE
      GOTO MAIN
```

Note that it's not just a BCF INTCON,GIE instruction that will be affected – it can be any instruction sequence that has the effect of clearing GIE, e.g. the following is also vulnerable:

```
MOVLW H'7F'
ANDWF INTCON,F
```

INTPROG7 is the final corrected version of INTPROG6. It uses two macros, **Enter_Critical_Section** and **Leave_Critical_Section** which expand to the necessary code sequences (see Listing 7a). The author prefers to use these as they make it very clear in the source listing what is going on – the code is almost self-documenting. Listing 7b shows how the macros are used in INTPROG7.

Readers who use MPASM are welcome to copy these macros and use them in their own programs. Diehard TASM users will have to use the code sequences, as TASM lacks a macro translator (*as do all EPE programmers. Ed*). An example of how the code would be used by an assembler that

does not recognise macros is shown in Listing 7c.

Hopefully, INTPROG7 can be used as a "model answer" for well-structured interrupt driven programs.

MULTIPLE INTERRUPTS

As mentioned earlier, more than one interrupt source can be enabled simultaneously. To illustrate this, INTPROG8 is an alternative version of INTPROG5 that uses timer interrupts and so has both the INTF and T0IF interrupts enabled. The heart of this program is shown in Listing 8.

The ISR checks for each interrupt, and also allows for both interrupts to have occurred. A critical section is used to prevent COUNT from being changed by the ISR while it is being read and possibly reset by the main loop.

Proof that both interrupts work correctly is that the l.e.d. is caused to flash because the TMR0 interrupt increments COUNT, and that it is caused to stop when the RB0 interrupt is triggered by touching the wire link from RB0 to pin 15.

It is suggested that you repeat Experiment 3 with INTPROG8.

Observant readers will spot one other change from INTPROG5. At the beginning of the critical section, the test for COUNT = SPEED is changed from:

```
XORWF COUNT,W
BTFSF STATUS,Z
to:
SUBWF COUNT,W
BTFSF STATUS,C.
```

LISTING 7a

```
; Macros
#DEFINE BANK0 BCF 0x03,5
#DEFINE BANK1 BSF 0x03,5
Enter_Critical_Section MACRO
    LOCAL __CS1
    __CS1 BCF INTCON,GIE
    BTFSF INTCON,GIE
    GOTO __CS1
    ENDM
Leave_Critical_Section MACRO
    BSF INTCON,GIE
    ENDM
```

LISTING 7b

```
MAIN:
    Enter_Critical_Section
    MOVF ISRCL,W ; copy ISR
    ; low byte counter
    MOVWF COUNTL
    MOVF ISRCH,W ; copy ISR
    ; high byte counter
    Leave_Critical_Section
    MOVWF COUNTH
```

LISTING 7c

```
CS1:BCF INTCON,GIE
    BTFSF INTCON,GIE
    GOTO CS1
    MOVF ISRCL,W ; copy ISR
    ; low byte counter
    MOVWF COUNTL
    MOVF ISRCH,W ; copy ISR
    ; high byte counter
    BSF INTCON,GIE
    MOVWF COUNTH
```


Can you think why this has been done? If you can't (or if you can and want to prove that you're right!), change this test in INTPROG8 back to how it is in INT-PROG5, reassemble INTPROG8 and re-run Experiment 3. (Hint: if the PIC appears to stop working, don't immediately reset it to try again – leave it for a minute or so.)

A detailed explanation is left as an "exercise for the student", as they say in the best textbooks, but if you can fully account for what you observe (it's all to do with equality!) then you have probably got a good understanding of interrupt loops, multiple interrupts, and the PIC instruction set.

MORE ON CRITICAL SECTIONS

Critical sections should be kept as short as possible. While a program is in a critical section, interrupts will be held off – after all that's why you had the critical section in the first place.

But holding interrupts off is likely to be undesirable for any length of time, because the reason you made things interrupts is in order to get the fastest response to them. So there's a trade off between minimising the delay to processing interrupts and getting your program to work robustly.

That's why, in INTPROG6 and INT-PROG7, ISRCH and ISRCL are copied to COUNTH and COUNTL, and then COUNTH and COUNTL are used in the calculation. This keeps the critical section down to three instructions while the copy is made.

If ISRCH and ISRCL had been used directly, the critical section would have been most of the main loop. Interrupts could only have been safely enabled for a short period at its end.

If multiple interrupts had occurred during the critical section, then all but one would have been lost. Indeed, there would then not have been much point in using interrupts at all – such a program might just as well have polled the TOIF flag at the end of the loop.

Critical sections are necessary whenever more than one variable set by the ISR needs to be accessed consistently by the main program, or where repeated access to the same single variable is needed.

If only one variable is set by the ISR, and the main program accesses it exactly once, it is probably safe not to use a critical section. This is because, as we saw above, instructions are atomic – an interrupt can only occur between instructions, so a single variable will either have been accessed, or it will not.

Nevertheless, the author *always* uses a critical section *whenever* any ISR variable, single or otherwise, is accessed by the main program.

The hard part about critical sections is understanding the notion behind them and getting their placement right. Once you've managed that, critical sections are easy to implement and involve minimal overhead.

Even if they are not strictly necessary, they are good practice, using them is a good habit to get into, there's no harm in a measure of belt and braces safety, and should a program ever need modifying in the future such that one becomes necessary, the structure is already there.

LISTING 8. Section of INTPROG8 which illustrates the use of two interrupt sources.

```
; interrupt setup
BSF INTCON,INTE      ; enable INTF interrupt
CLRf TMR0             ; clear internal clock count-up
CLRf COUNT           ; clear clock wrapped count
BCF INTCON,TOIF       ; clear the TMR0 wrapped flag
BSF INTCON,TOIE       ; enable timer interrupts
BSF INTCON,GIE        ; enable global interrupts

; data initialisation
BSF PORTA,0          ; turn on the LED

; main loop
MAIN: MOVLW SPEED      ; about 10 bumps/sec at 2MHz clock
      Enter_Critical_Section
      SUBWF COUNT,W    ; sets C if COUNT = W
      BTFSF STATUS,C    ; test C
      GOTO A2           ; C clear so COUNT < SPEED
      CLRf COUNT       ; reset the wrapped count
      Leave_Critical_Section
      MOVLW 1          ; wraps COUNT = SPEED so
      XORWF PORTA,F    ; toggle RA0
      GOTO MAIN        ; repeat main loop

A2:   Leave_Critical_Section
      GOTO MAIN        ; and repeat main loop

; Interrupt service routine
ISR:  MOVWF SAVEW      ; save W
      SWAPF STATUS,W
      MOVWF SAVES      ; save STATUS
      BANK0            ; ensure bank 0 set
      INCF ICOUNT,F   ; bump interrupt count
      BTFSF INTCON,INTF ; test INTF
      GOTO TMR         ; not an RB0 interrupt – try timer

; INTF interrupt
NOP                      ; nothing to do for this demo!
BCF INTCON,INTF         ; clear the interrupt

TMR:  BTFSF INTCON,TOIF ; test INTF
      GOTO POP         ; not a timer interrupt

; timer interrupt
INCF COUNT,F           ; bump clocks wrapped count
BCF INTCON,TOIF       ; clear the interrupt

POP:  SWAPF SAVES,W    ; restore STATUS
      MOVWF STATUS
      SWAPF SAVEW,F    ; restore W
      SWAPF SAVEW,W
      RETFIE          ; exit ISR
```

ISR BREVITY

ISRs should be kept as short as possible too. This is partly because, in their turn, ISRs disrupt the main program. Timings in the main loop become difficult to predict if a lengthy ISR is going off all the time.

Also, interrupts are disabled while you're in the ISR, so other interrupts, and repeat occurrences of the same interrupt, will all be held pending and not handled until the ISR completes processing the current interrupt. At worst, interrupts could be lost. As much processing as possible should be left to the main program loop.

But the main reason for keeping ISRs short is that they are next to impossible to debug. If you have a bug in an ISR, then you will find that simulators and ICD (in-circuit development) tools give you little if any help.

When testing, it's hard to control exactly when an ISR runs and, as we've seen, that can be very important. You generally cannot put much debug into an ISR without disrupting things so much that your problem is masked, or changes, or simply can't be reproduced. Bugs in the ISR will tend to produce symptoms varying from the just strange to the totally bizarre.

By far the best approach is to keep ISRs short, sweet, and above all simple, so that you don't create problems in the first place. Prevention is much, much better than cure here.

A good ISR should do the following, and only the following:

- save Context
- establish its own Context
- test the flags thoroughly to be sure which event(s) have occurred
- increment a counter or two, maybe set a Boolean (flag) to record that it has run
- take emergency action only (e.g. if an endstop microswitch has been triggered, turn off the motor)
- clear the interrupt(s) that have occurred
- restore Context
- exit

STACK

The mechanism used by the PIC when the ISR is entered is rather like a CALL instruction. The address of the next instruction to be executed when the ISR exits is pushed onto the Stack, and popped from the Stack by the RETFIE instruction.

So it is worth noting that if you use interrupts, you effectively lose one level of Stack. That won't affect most programs because there are eight levels available and programs rarely nest CALLs anything like this deep.

However, if you do "blow the Stack" there is no STATUS or other warning to let you know you've done it – not that it matters much, because your program will really go bananas then!

CONCLUSION

The author hopes that all this hasn't put you off experimenting with interrupts. The

reverse, in fact – armed with this information he hopes that many people will now feel more confident to have a go themselves.

What he does hope to have done, however, is to have convinced you that interrupts and poor software do not mix very well, and to have encouraged the use of good software design and implementation techniques.

If so, then a successful outcome to experimentation is much more likely.

OBTAINING SOFTWARE

The demonstration software for this article is available from the EPE Editorial

office on 3.5-inch (for which a nominal handling charge applies), or free from the EPE web site. See this month's *Shoptalk* page for more details.

PCLATH

An article on the correct use of the bank and block switching command PCLATH is scheduled for a forthcoming issue. It is of special relevance to using tables that are longer than 256 jumps and to using PIC16F87x program locations above 2K.

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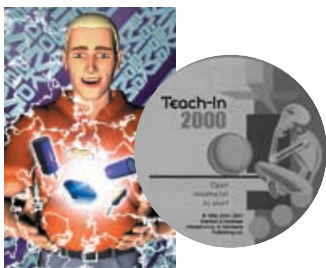
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become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

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GETTING THE MOST FROM YOUR MULTIMETER

R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic products.

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DIGITAL GATES AND FLIP-FLOPS

Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

200 pages **Order code PC106 £9.95**

Music, Audio and Video

QUICK GUIDE TO ANALOGUE SYNTHESIS

Ian Waugh

Even though music production has moved into the digital domain, modern synthesizers invariably use analogue synthesis techniques. The reason is simple – analogue synthesis is flexible and versatile, and it's relatively easy for us to understand. The basics are the same for all analogue synths, and you'll quickly be able to adapt the principles to any instrument, to edit existing sounds and create exciting new ones. This book describes: How analogue synthesis works; The essential modules every synthesiser has; The three steps to synthesis; How to create phat bass sounds; How to generate filter sweeps; Advanced synth modules; How to create simple and complex synth patches; Where to find soft synths on the Web.

If you want to take your synthesiser – of the hardware or software variety – past the presets, and program your own sounds and effects, this practical and well-illustrated book tells you what you need to know.

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QUICK GUIDE TO MP3 AND DIGITAL MUSIC

Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

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ELECTRONIC MUSIC AND MIDI PROJECTS

R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing in this respect.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

124 pages **Order code PC116 £10.95**

THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN

Robert Charles Alexander

This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, and whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first electronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

420 pages **Order code NE32 £15.99**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

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PC MUSIC – THE EASY GUIDE

Robin Vincent

How do I make music on my PC? Can I record music onto my PC? What's a sequencer? How can I get my PC to print a music score? What sort of a soundcard do I need? What hardware and software do I need? How do I connect a keyboard to my PC?

Just a few of the questions you've probably asked. Well, you'll find the answers to all these questions, and many more, in this book. It will show you what can be done, what it all means, and what you will need to start creating your own music on your PC. It's an easy read, it's fully illustrated and it will help you understand how a computer can be used as a creative music tool.

It covers soundcards, sequencers, hard disk digital audio recording and editing, plug-ins, printing scores with notation software, using your PC as a synthesiser, getting music onto and off the Internet, using Windows, sample PC music set-ups, FAQs, a glossary, advice on hardware and software, and a list of industry contacts.

116 pages **Order code PC117 £11.95**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION

R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

96 pages **Order code BP277 £4.49**

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Circuits, Data and Design

PRACTICAL ELECTRONIC FILTERS

Owen Bishop

This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.

The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rhythm sequencer and a multi-voiced electronic organ.

Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.

88 pages

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH

With FREE Software: Number One Systems – EASY-PC

FREE SOFTWARE

Professional XM and Pulsar (Limited Functionality) Richard Monk

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages (large format)

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50 SIMPLE LED CIRCUITS

R. N. Soar

Contains 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components – the light-emitting diode (LED). Also includes circuits for the 707 common anode display.

64 pages

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A BEGINNER'S GUIDE TO TTL DIGITAL ICs

R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the 'real world'.

142 pages

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HOW TO USE OP.AMPS

E. A. Parr

This book has been written as a designer's guide covering many operational amplifiers, serving both as a source book of circuits and a reference book for design calculations. The approach has been made as non-mathematical as possible.

160 pages

Order code BP88

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CIRCUIT SOURCE BOOK 2

R. A. Penfold

This book will help you to create and experiment with your own electronic designs by combining and using the various standard 'building blocks' circuits provided. Where applicable, advice on how to alter the circuit parameters is provided.

The circuits covered are mainly concerned with signal generation, power supplies, and digital electronics.

The topics covered in this book include: 555 oscillators; sinewave oscillators; function generators; CMOS oscillators; voltage controlled oscillators; radio frequency oscillators; 555 monostables; CMOS monostables; TTL

monostables; precision long timers; power supply and regulator circuits; negative supply generators and voltage boosters; digital dividers; decoders, etc; counters and display drivers; D/A and A/D converters; opto-isolators, flip/flops, noise generators, tone decoders, etc.

Over 170 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.

192 pages

Order code BP322

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Project Building & Testing

ELECTRONIC PROJECTS FOR EXPERIMENTERS

R. A. Penfold

Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded 'seen it all before' syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.

The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red 'torch', Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages

Order code BP371

£5.45

ELECTRONIC PROJECT BUILDING FOR BEGINNERS

R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting 'problem' projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages

Order code BP392

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PRACTICAL FIBRE-OPTIC PROJECTS

R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an

innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages

Order code BP374

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RADIO BYGONES

We also carry a selection of books aimed at readers of *EPE's* sister magazine on vintage radio *Radio Bygones*. These books include the *Comprehensive Radio Valve Guides* (five books with a Free copy of the Master Index) for just £15. Also Jonathan Hill's excellent *Radio Radio*, a comprehensive book with hundreds of photos depicting the development of the British wireless set up to the late 1960s.

The three volumes of our own *Wireless For the Warrior* by Louis Meulstee are also available. These are a technical history of radio communication equipment in the British Army from pre-war through to the 1960s.

For details see the shop on our UK web site at www.epemag.wimborne.co.uk or contact us for a list of *Radio Bygones* books.

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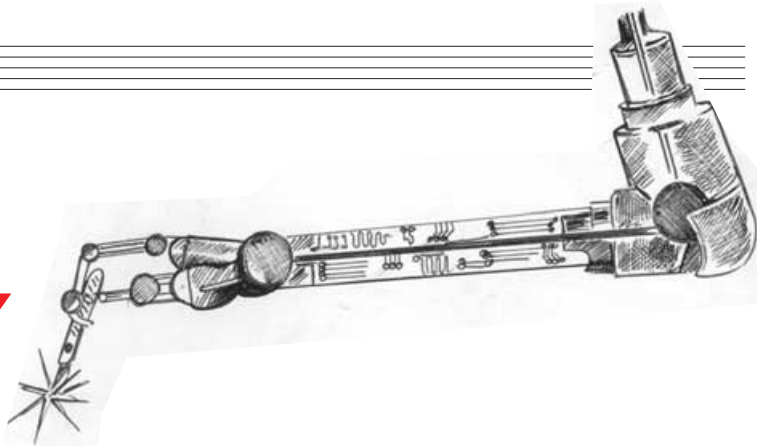
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CIRCUIT SURGERY

ALAN WINSTANLEY
and IAN BELL



In this month's column we examine the principles of screening of signal wires and the problems caused by ground loops. A new transceiver has battery problems too.

Potential Problems

Our thanks to **Gerard Galvin** who emailed to ask a few questions about earthing and shielding, topics which we will look at in turn. His first point concerns the provision that some bench power supplies (e.g. Andy Flind's *Versatile Bench Power Supply* in *EPE* Jan 2002) have for a choice of positive, negative or floating earth (ground) output terminals, so that other earthed equipment such as oscilloscopes can be safely connected to any circuit on test.

Gerard asks "If both circuit and test equipment are at the same potential, why can there be a problem?"

There are two possible problems with "earthing" on supplies and test equipment; one relates to interference and measurement accuracy, which we will return to in a moment. The other problem relates to the possibility of short circuits.

An oscilloscope probe will usually have its outer wire (screen) connected directly to the chassis and therefore to the mains Earth. This means that if you clip the 'scope probe ground anywhere in a circuit, you will connect that part of the circuit directly to mains earth. (In the USA and elsewhere, the term "ground" is used instead of "earth".)

If the power supply 0V rail is also grounded (to mains earth) in the apparatus then the oscilloscope probe's ground terminal will cause that part of the circuit to be shorted to the circuit's 0V rail, affecting its operation or even damaging it, see

Fig.1. If the power supply output is *floating* or isolated, so that there is no d.c. path to mains earth, then connecting a single scope ground should not cause a short.

Ground Loops

The interference problem is caused by *earth loops*. Gerard also asked us to explain this, commenting: "Why was it sometimes necessary to link the casings of one's stereo deck and amplifier together? (I think I was even advised once to disconnect the earth from one of the appliance's 3-pin mains plugs)."

Have a look at Fig.2, which illustrates a mains earth loop between two circuits (instruments, hi-fi components etc). This topic is also one that we're covering in our current educational series, *Teach-In 2002: Making Sense of the Real World*. Noise and shielding are important aspects of using sensors as our series shows, as signals and test measurements can be adversely affected by unwanted noise.

The resistor labelled R_G represents the resistance of the earth wire of a test lead (e.g. an oscilloscope probe) or an audio cable (if Circuit 1 and Circuit 2 are hi-fi separates) or some other interconnection between the circuits. This lead links the earths of the two circuits together. The two circuits are connected to mains earth via their mains leads, and thus they are linked

via the mains wiring, so completing the "loop".

The loop will act like the secondary of a transformer and pick up magnetic interference such as mains hum, and may also act like an antenna picking up radio frequency interference (r.f.i.) as well. That interference causes a current I_L to flow in the ground loop, which in turn causes an additional voltage drop (equivalent to the value of $I_L R_G$) across the resistance, R_G , of the ground connection between the equipment or sub-circuits. This voltage is a source of mains hum in hi-fi components or measurement errors in test equipment.

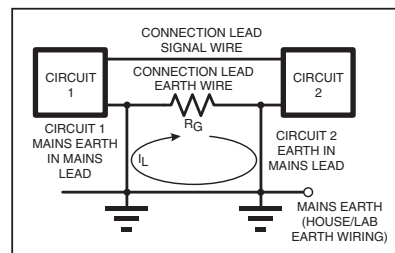


Fig.2. A mains "ground loop" formed from a resistance in the wire R_G .

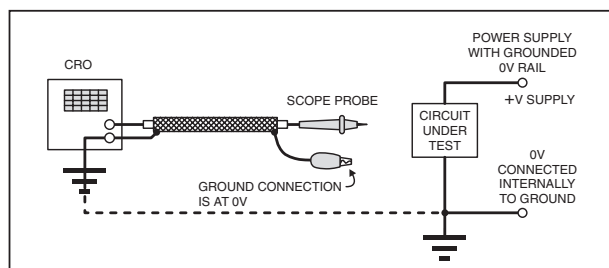
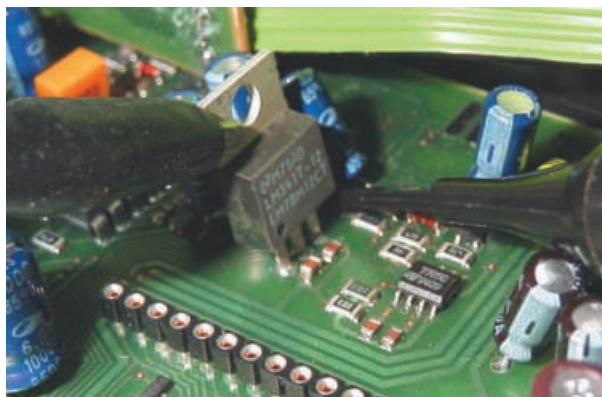


Fig.1. A grounded 0V connection can affect circuits under test, sometimes a "floating" supply is preferable.



Connecting an oscilloscope ground probe onto a regulator tab. If a grounded power supply is being used, care is needed to ensure damage will not be caused by shorting any part of the circuit under test (e.g. the regulator tab) to the 0V rail via the scope probe and earth.

Hum Bug

Two possible solutions to this problem were actually given by Gerard in his question. The first is to reduce the effective value of R_G by providing a very low resistance path between the earth connections of the two circuits (by linking the chassis or casings in this case).

The second is to break the loop by connecting *only one* of the circuits to mains earth (in practice, by disconnecting the Earth from one of the appliance's 3-pin plugs). It might not always be recommended to disconnect an earth terminal in this way because of possible safety implications; however a lot of equipment today is double-insulated and runs from a twin-core power cord, with no separate earth being used anyway.

Gerard goes on to ask "I don't know if this is connected in any way, but how does a simple twisted pair reject radio interference?"

Again it is a matter of loops acting like transformer secondaries or antennae. The smaller the area of any loops then the smaller the interference pick-up must be. Put simply, a twisted cable has smaller loops than two individual wires that could potentially form a very large loop.

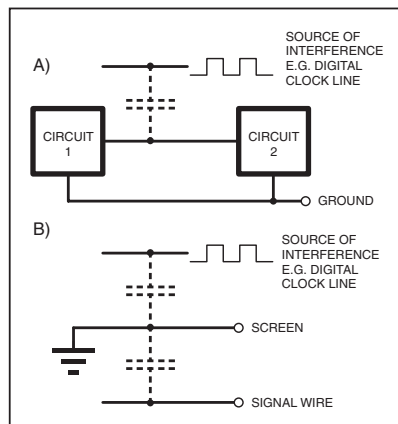


Fig.3a. Capacitive coupling of interference and (b) equivalent circuit for screened cable with capacitively coupled interference grounded by the screen.

On Screen

Gerard's final question is "How does screening work and does it only work if the negative (or earth) is on the outside?"

Well, *capacitive coupling* can pick up interference, when there is in effect a form of capacitor created which links a source of interference to the wire carrying the signal. This is illustrated in Fig. 3. When we screen a cable by surrounding it with a braid then the interference is coupled to the screen instead.

The screen is equivalent to inserting a capacitance in series with the interference-coupling capacitance and connecting the centre point to ground. The interference picked up by the screen is therefore harmlessly shorted to ground (see Fig.3b). For this to work the screen obviously has to be on the outside and connected to earth or 0V.

Interference, screening, and grounding are important topics and you can read more in Part 6 of *Teach-In 2002*. Even then we

have not covered every aspect of these matters, so if anyone has any further questions please let us know. *IMB*.

Transceiver Supply Surprise

Mr. George Jacob writes from Mid Glamorgan in Wales:

"I have a query about a Yaesu FT290 RII 2-metre transceiver I purchased recently. It came minus the Nickel-Cadmium rechargeable batteries or a charger!"

I purchased new NiCads (9 x 2500mAh "C" cells) but I cannot buy a suitable charger to charge all of the cells as they are no longer made. The approved charger provides 13.05V d.c. at 165mA. One type I have been offered is rated at 13.5V at 700mA, I wondered if this would work? Can you also explain more about mA?"

I can't usually help with commercial equipment problems but I didn't want to see you fry an expensive new battery pack, so here goes. I guessed that the battery pack is probably a separate removable unit (like a video camera pack) which must be recharged externally, so it then boiled down to how "intelligent" the battery pack was (if at all), and what to suggest for a suitable external charger.

To answer your other queries first. We mentioned in last month's *Circuit Surgery* that batteries have a capacity measured in ampere-hours (Ah) or milliampere-hours (mAh) – it is an indication of how much current they can supply before the voltage fell to too low a level and it was time to recharge.

An individual 1.2V cell should be considered "flat" when its voltage has dropped to about 0.9V or so. The term "mA" is simply short for milliamperes, or 1/1,000 amp, a measurement of current flow. Putting your nine cells in series creates a 10.8V 2500mAh battery pack with a capacity of 2.5 amps for one hour.

Be Constant

The general rule is to charge a NiCad battery with a constant current of (capacity divided by 10) for a period of say 14 to 16 hours maximum. You mentioned a manufacturer's rating of 165mA which sounds about right. However, I am very concerned about using the suggested 700mA battery charger, as it sounds like a brutal "fast charger".

One fast 2-hour charger in my possession is intended for eight "AA" cells at a time, but when I measured the cell's temperatures they were an astonishing 65°C which is 30 per cent higher than the battery's maximum rating; the charger and batteries were way too hot. I have had several fast chargers overheat and fail altogether, taking the batteries with them.

Excessive temperature is a real killer of cells and overcharging can cause serious damage, so matching your batteries' charge current and time is very important, and using an intelligent charger is recommended. The better ones will "cycle" the batteries properly by discharging them first.

I searched for Yaesu UK's web site (www.yaesu.co.uk), from which I obtained an email address. My thanks to Sam Ruddy of Yaesu UK Technical Support who was extremely helpful, replying by return with some suggestions.

Sam explained that their original NC-26 was a simple wall charger which plugged into the side of the FBA-8 battery pack that held the NiCads. There is no charging circuit built into the battery pack itself, so you really need a proper external NiCad charger.

As the NC-26 is no longer available they recommend the basic RS plug-top NiCad charger, part number 250-1397 (phone 01536 444079, or see <http://rswww.com>). This provides a constant current of 60mA and can handle 1 to 12 cells. It has i.e.d. charge status and short circuit/reverse polarity protection.

Also available is an RS charger (code 250-1252) which has an adjustable current of 50mA to 400mA, and a "proper" quick charge unit (code 250-1404) with a built-in timer and automatic sensing and switching to trickle charge.

Yaesu UK agrees that the trouble with using the 700mA adaptor is making sure it does not overcharge those expensive batteries. It's your choice, personally I think the basic RS unit, although slow, will be the kindest on your batteries, or go for the fast charge with timer.

Eco Warrior

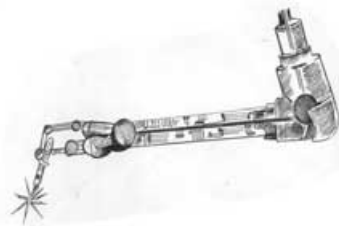
Lastly, something I have been itching to say for months – for all my NiCad or NiMH battery charging I am very pleased with my Saitek Eco-Charger with micro-processor control, available from CPC (Part No. BT00283, approximately £35), telephone 08701 202530.

This desktop unit will discharge and recharge a mixture of different sizes (AA to D-size) on its four channels all at the same time, it has a useful i.c.d. display and most importantly it actually recharges zinc carbon and alkaline batteries several times over as well. An alternative type is the Goodmans GBC1150 (Part No. BT02327, approx £26) although I have not tested it.

Regular readers know how I feel about throwing toxic batteries, especially NiCads, into the ordinary domestic waste due to the pathetic state of UK recycling facilities, so anything that helps the environment in this way is extremely welcome. *ARW*.

CIRCUIT THERAPY

Circuit Surgery is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset, BH22 9ND. E-mail (no attachments) alan@epemag.co.uk. Please indicate if your query is not for publication. A personal reply cannot be guaranteed but we will try to publish representative answers in this column.



PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. Tel: 01202 873872; Fax 01202 874562; E-mail: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.wimborne.co.uk/shopdoor.htm.** Cheques should be crossed and made payable to *Everyday Practical Electronics* (Payment in £ sterling only).

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Boards can only be supplied on a payment with order basis.

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Freezer Alarm (Multi-project PCB)	932	£3.00
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★Interior Lamp Delay	244	£7.88
Mains Cable Locator (Multi-project PCB)	932	£3.00
Vibralarm	NOV '99 230	£6.93
Demister One-Shot	245	£6.78
★Ginormous Stopwatch – Part 1	246	£7.82
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Dummy PIR Detector	–	–
★PIC16F87x Extended Memory	Software only	–

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Solar-Powered Power Supply & Voltage Reg.		
MSF Signal Repeater and Indicator		
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Shortwave Loop Aerial	310	£5.07
★Digitimer – Main Board	311	£6.50
– R.F. Board	312	£4.36
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Perpetual Projects Uniboard–3	SEPT '01 305	£3.00
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PIC Toolkit Mk3	319	£8.24
Perpetual Projects Uniboard–4. Gate Sentinel, Solar-powered Bird Scarer and Solar-Powered Register	305	£3.00
Teach-In 2002 Power Supply	NOV '01 320	£4.28
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– Display Board (double-sided)	324	£12.00
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– Analogue	329	£7.61
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★PIC Magic Musick	332	£5.87
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★PIC Spectrum Analyser	FEB '02 334	£7.13
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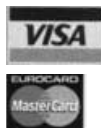
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